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PENSOFT

Taxonomic notes on the species of the genus *Micrasterias* (Desmidiaceae, Conjugatophyceae) from the Metropolitan Region of Salvador, Bahia, Brazil

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Abstract

We present the results of a taxonomic survey of the genus *Micrasterias* in the Metropolitan Region of Salvador (MRS), Bahia, northeastern Brazil during 2007–2010 and 2014–2015. A total of 275 phytoplanktonic and periphytic samples from 11 municipalities were analyzed. The samples were collected using a plankton net with 20 µm mesh or squeezed from macrophytes. Twenty-nine taxa were identified, which 20 have their geographic distributions expanded. Only *M. pinnatifida* was considered frequent, occurring in 9 municipalities, while we classified 21 species as rare in the study area. Our results emphasize the importance of the conservation of aquatic bodies in the MRS for the maintenance of biological diversity of desmids and other aquatic organisms.

Key words

Algae; desmids; floristic survey; taxonomy.

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Introduction

The Metropolitan Region of Salvador (MRS), which is located in the Atlantic Forest biome, has a diversity of natural resources (e.g., hydrographic basins and various plant phytophysiognomies) which are protected by 8 Áreas de Proteção Ambiental (APA; EPA, Environmental Protected Areas): APA Baía de Todos os Santos, APA do Cobre/São Bartolomeu, APA Joanes-Ipitanga, APA Lagoas de Guarajuba, APA Lagoas e Dunas do Abaeté, APA Litoral Norte, APA Plataforma Continental, and APA Rio Capivara (INEMA 2018). Like most Brazilian metropolitan regions, MRS has experienced severe anthropogenic pressure due to increased rates of urbanization and tourism in the region. These activities have exerted strong pressure on the environment, affecting both aquatic and terrestrial ecosystems, which may eventually cause irreparable damage to the biodiversity therein (INEMA 2018).

The genus *Micrasterias* C.Agardh ex Ralfs comprises approximately 75 currently accepted species (Guiry and Guiry 2018) of unicellular green algae, which exhibit a high level of cellular complexity. The cells are formed by 2 identical halves (semicells) that are differentiated into an apical lobe and a lateral lobe; the latter is subdivided into lobules to the fifth order, which gives these organ-

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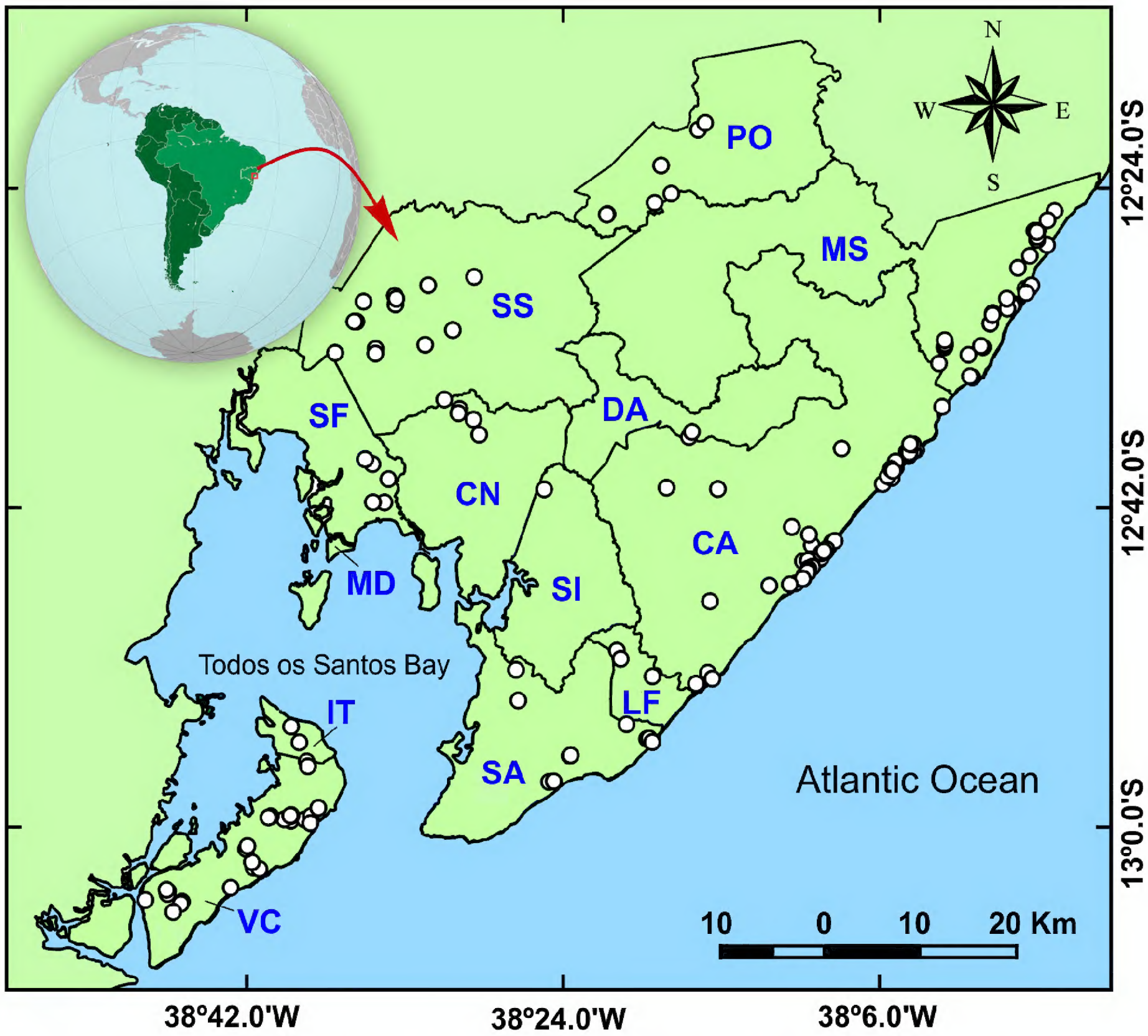


Figure 1. Map of the Metropolitan Region of Salvador with the collecting points (white circles) in the municipalities sampled: CA = Camaçari, CN = Candeias, DA = Dias d'Ávila, IT = Itaparica, LF = Lauro de Freitas, MD = Madre de Deus, MS = Mata de São João, PO = Pojuca, SA = Salvador, SF = São Francisco do Conde, SS = São Sebastião do Passé, SI = Simões Filho, VC = Vera Cruz.

isms a highly branched morphology (Škaloud et al. 2011, Neustupa 2017). According to Škaloud et al. (2011), the genus comprises 8 phylogenetic lines that also include taxa previously placed in other genera of desmids, such as *Cosmarium* Corda ex Ralfs, *Staurodesmus* Teiling, and *Triploceras* Bailey.

The great majority of *Micrasterias* taxa possess wide geographic distributions, especially in tropical and subtropical regions. Like other members of the Desmidiaceae, they inhabit almost exclusively aquatic environments, and are characteristic of oligotrophic aquatic bodies that are well oxygenated and with a slightly acidic pH, which makes these organisms excellent indicators of water quality as they have high sensitivity to any form of contaminant in the aquatic environment (Brook 1981, Bicudo and Menezes 2017, Coesel 1996, Moresco et al. 2009, Volland et al. 2011).

Until now, 28 taxa of *Micrasterias* were recorded for the MRS, in the municipalities of Camaçari (Oliveira et al. 2009), Itaparica and Vera Cruz (Santos et al. 2016), and Mata de São João (Oliveira 2011, Oliveira et al. 2017). Among these taxa are *M. americana* (Ehrenb.) Ralfs var. *bahiensis* I.B.Oliveira, C.E.M.Bicudo & C.W.N.Moura (Oliveira et al. 2009), described as new from material collected in Camaçari, and *M. furcata* var. *dichotoma* (Wolle), recorded from Brazil for the first time from material collected in Vera Cruz (Santos et al. 2016).

Herein, we present the results of a taxonomic inventory of the genus *Micrasterias* in 11 municipalities of the MRS. We provide information on the geographic distribution of taxa, population metrics, illustrations, and taxonomic notes.

Methods

Study area. The MRS occupies an area of 4,375,123 km² and is composed of 13 municipalities (Fig. 1): Camaçari, Candeias, Dias d'Ávila, Itaparica, Lauro de Freitas, Madre de Deus, Mata de São João, Pojuca, Salvador, São Francisco do Conde, São Sebastião do Passé, Simões

Table 1. Taxonomic inventory of the *Micrasterias* taxa in the Region Metropolitan of Salvador identified in the present and previous studies (recorded in the literature: 1= Oliveira et al (2009); 2= Oliveira (2011); 3= Santos et al (2016); 4= Oliveira et al (2017)). CA= Camaçari, CN= Candeias, DA= Dias D'Ávila, IT= Itaparica, LF= Lauro de Freitas, MS= Mata de São João, PO= Pojuca, SA= Salvador, SF= São Francisco do Conde, SS= São Sebastião do Passé, VC= Vera Cruz. (-)= Absent.

Taxa	Cells measurements (µm)				References to RMS municpalities										
	Length	Width	Polar lobe	Isthmus	CA	CN	DA	IT	LF	MS	PO	SA	SF	SS	VC
M. abrupta West & G.S.West var. *abrupta*	43–60	47–63	27–40	10–14	—	—	—	—	—	2	—	—	—	—	3
M. alata G.C. Wallich var. *alata*	180–230	175–207 (–221)	87–121	19–25	1	—	—	—	—	2	—	—	—	—	3
M. americana (Ehrenberg) Ralfs var. *bahiensis* I.B. Oliveira, C.E.M. Bicudo & C.W.N. Moura		120–130	76–84	25–27	1	—	—	—	—	—	—	—	—	—	—
M. arcuata Bailey var. *arcuata*	66–71	50–63	48–51	11–12	—	—	—	—	—	—	—	—	—	—	—
M. arcuata Bailey var. *expansa* (Bailey) Nordstedt	66–75	(46–) 52–57	20–25	11–12	—	—	—	—	—	2, 4	—	—	—	—	—
M. arcuata Bailey var. *robusta* Borge	50–70	40–55	21–32	10–12	—	—	—	—	—	2	—	—	—	—	—
M. arcuata Bailey var. *subpinnatifida* West & G.S.West	65–78	65–86	50–65	10–17	1	—	—	—	—	2	—	—	—	—	—
M. borgei W.Krieger var. *borgei*	(225–) 248–320	220–280	54–70	32–38	1	—	—	—	—	—	—	—	—	—	3
M. denticulata Brébisson ex Ralfs var. *denticulata*	277	195	58	27	—	—	—	—	—	2, 4	—	—	—	—	—
M. foliacea Bailey ex Ralfs var. *foliacea*	75–100	94–105	40–50	15–19	1	—	—	—	—	2	—	—	—	—	3
M. furcata C.Agardh ex Ralfs var. *furcata*	148–176	130–165	49–71	15–25	1	—	—	—	—	2	—	—	—	—	3
M. furcata var. *dichotoma* (Wolle) Růžička	140–175	108–157	42,5–71	15–25	—	—	—	—	—	—	—	—	—	—	3
M. laticeps Nordstedt var. *laticeps*	110–195	118–225	87–117,5	10–25	1	—	—	—	—	2	—	—	—	—	3
M. laticeps Nordstedt var. *acuminata* W.Krieger	85–102	97–132	87–117	10–25	1	—	—	—	—	2	—	—	—	—	—
M. laticeps Nordstedt var. *ampliata* W.Krieger	195–199	166–173	190–191	27–30	—	—	—	—	—	2,4	—	—	—	—	—
M. mahabuleshwarensis J.Hobson var. *mahabuleshwarensis*	153–162	106–124	77–80	23–24	1	—	—	—	—	2	—	—	—	—	3
M. mahabuleshwarensis J. Hobsen var. *ampullacea* (W.M. Maskell) Nordstedt	138–165	103–122	56–82	22–30	1	—	—	—	—	2	—	—	—	—	—
M. papillifera Brébisson ex Ralfs var. *glabra* Nordstedt	135–136	119–124	37–39	19	—	—	—	—	—	2	—	—	—	—	—
M. pinnatifida (Kützing) Ralfs var. *pinnatifida*	50–75	55–75	25–55(–70)	9–17	1	—	—	3	—	2	—	—	—	—	3
M. quadridentata (Nordstedt) Grönblad	298–420	260–410	67–70	34–40	—	—	—	—	—	—	—	—	—	—	—
M. radians Turner	125–157	117–142	50–65	15–27	—	—	—	3	—	—	—	—	—	—	3
M. radiosa Ralfs var. *radiosa*	147–190 (– 253)	147–189 (– 238)	19–33	15–29	—	—	—	3	—	2, 4	—	—	—	—	3
M. radiosa Ralfs var. *elegantior* (G.S.West) Croasdale	165–182,5	160–194	28–34	15–21	1	—	—	—	—	2	—	—	—	—	3
M. radiosa Ralfs var. *ornata* Nordstedt f. *ornata*	146–242 (– 270)	141–255	16–26	24–47	—	—	—	—	—	2	—	—	—	—	3
M. radiosa Ralfs var. *ornata* Nordstedt f. *aculeata* (W.Krieger) Croasdale	(173 –) 243–274	(175 –) 218–238	(28 –) 43–49	27–30	—	—	—	—	—	2	—	—	—	—	3
M. rotata (Greville) ex Ralfs var. *rotata*	(180 –) 272–322	238–285	75–89	30–80	1	—	—	3	—	—	—	—	—	—	3
M. thomasiana Archer var. *rotata* (Nordstedt) Grönblad	266–371	240–332	30–44	48–67	—	—	—	—	—	2	—	—	—	—	3
M. torreyi Bailey ex Ralfs var. *nordstedtiana* (Hieronymus) Schmidle	187– 273	185–250	48–58	31–35	—	—	—	—	—	—	—	—	—	—	—
M. truncata (Corda) Brébisson ex Ralfs var. *pusilla* G.S.West	50–67	55–75	35–55	9–17	1	—	—	—	—	2	—	—	—	—	—

Filho, and Vera Cruz (IPEA 2015). Located in the Atlantic Forest biome, the MRS is characterized by a warm and humid climate with little variation (Nunes 1999) and an annual cycle defined by basically 2 seasons, a rainy season from January to July and a dry season from August to December (Grande et al. 2012). According to Braga et al. (1998), mean annual rainfall for the region ranges from about 1200 mm to 1500 mm, and the annual average temperature is approximately 25 °C.

Sampling and taxonomic analyses. We analyzed 275 samples from 11 of the 13 municipalities of the MRS (taxa of *Micrasterias* were not recorded in both Madre de Deus and Simões Filho); 133 samples were collected during 2007–2010 and 142 from 2014–2015. Periphytic material was obtained through the squeezing of macrophytes, while plankton were collected using a plankton net with 20 µm mesh.

We examined our material under an Olympus LX35 Optical Microscope and photographed using a MicroPublisher - QImaging MP5.0-RTV-CLR-10-C digital camera. The samples were preserved in Transeau's solution, following Bicudo and Menezes (2017), and incorporated into the liquid collection of the State University of Feira de Santana Herbarium (HUEFS) after analysis.

Frequencies of occurrence for each species of *Micrasterias* identified were calculated for the MRS and for each of the 11 municipalities, by considering the number of samples in which each taxon occurred in relation to the total number of samples collected ($n = 275$). Frequency categories followed Matteucci and Colma (1982), as follows: > 70% (very frequent, VF); ≤ 70% and > 40% (frequent, F); ≤ 40% and > 10% (occasional, O); and ≤ 10% (rare, R).

A Venn diagram was prepared showing the distribution of *Micrasterias* taxa richness among the 5 largest APAs within the MRS (Baía de Todos os Santos, Joanes-Ipitanga, Lagoas de Guarajuba, Litoral Norte, and Rio Capivara) using software available at the Bioinformatics and Evolutionary Genomics (2018) website.

Results

Analysis of the 275 samples from 11 municipalities of the MRS revealed the occurrence of 29 taxa corresponding to 19 species, 12 typical varieties, and 14 non-typical varieties of their respective species, as well as 2 taxonomic forms (Table 1).

Micrasterias abrupta West & G.S.West var. *abrupta*, 1896

Figure 2

Material examined. Brazil, Bahia, Camaçari, Arembepe, 02/II/2015, M.A. Santos et al. s/n. (HUEFS 219841); Candeias, Lagoon - BR 324, 12/IX/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219806); Mata de São João, Praia do Forte, 14/II/2009, I.B. Oliveira and C.W.N. Moura, s/n. (HUEFS 155711); Salvador, Av. Paralela, 31/III/2014, C.W.N. Moura et al. s/n. (HUEFS 219749); São Sebastião do Passé, Santo André, 15/XI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219815); Vera Cruz, Lagoon near to BA-532, 23/VII/2015, M.A. Santos and C.A. Ribeiro s/n. (HUEFS 219233).

Notes. Although this species is easy to recognize, according to Bicudo and Sormus (1981) the morphology of the polar lobe may vary. Among the MRS samples the polar lobe was either rectilinear or slightly convex, with 2-denticulate or only 1-denticulate extremities. The taxon generally occurs in oligotrophic to mesotrophic, slightly acidic (pH < 7.4) environments, where they make up the metaphyton or periphyton (Felisberto and Rodrigues 2005, Sophia et al. 2005, Silva and Felisberto 2015). Despite being recorded in more than half of the municipalities studied, we consider it rare in the MRS, occurring in only 17 of the 275 samples analyzed (Table 2).

Micrasterias alata G.C. Wallich var. *alata*, 1860

Figure 3

Material examined. Brazil, Bahia: Camaçari, Areias, 02/II/2015, M.A. Santos et al. s/n. (HUEFS 219843); Lauro de Freitas, Jambeiro, 26/I/2015, M.A. Santos, s/n. (HUEFS 219832); Salvador, Lagoon near to FTC, 13/XII/2014, M.A. Santos et al. s/n. (HUEFS 219827); Mata de São João, Imbassaí, 11/I/2009, I.B. Oliveira and C.W.N. Moura, s/n. (HUEFS 155598); Vera Cruz, Estrada Ponta Grossa, 05/XII/2015, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219221).

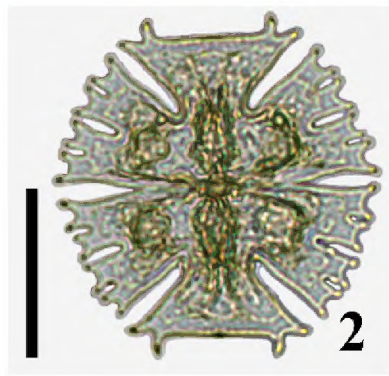
Notes. According Ribeiro et al. (2015), the presence of 3-lobulate, wing-like basal lobes confer *M. alata* var. *alata* a characteristic morphology that distinguishes it from other members of the genus. This species was found in the municipalities of Camaçari, Lauro de Freitas, Mata de São João, Salvador, and Vera Cruz. We classify it as occasional in the MRS (Table 2).

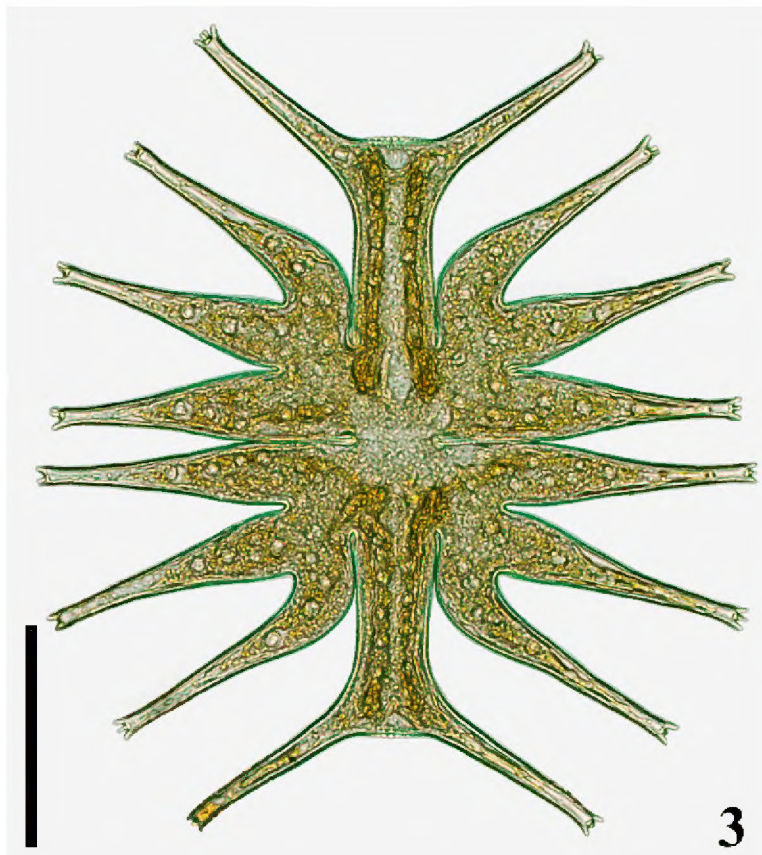
Micrasterias americana (Ehrenberg) Ralfs var. *bahiensis* I.B. Oliveira, C.E.M. Bicudo and C.W.N. Moura, 2009

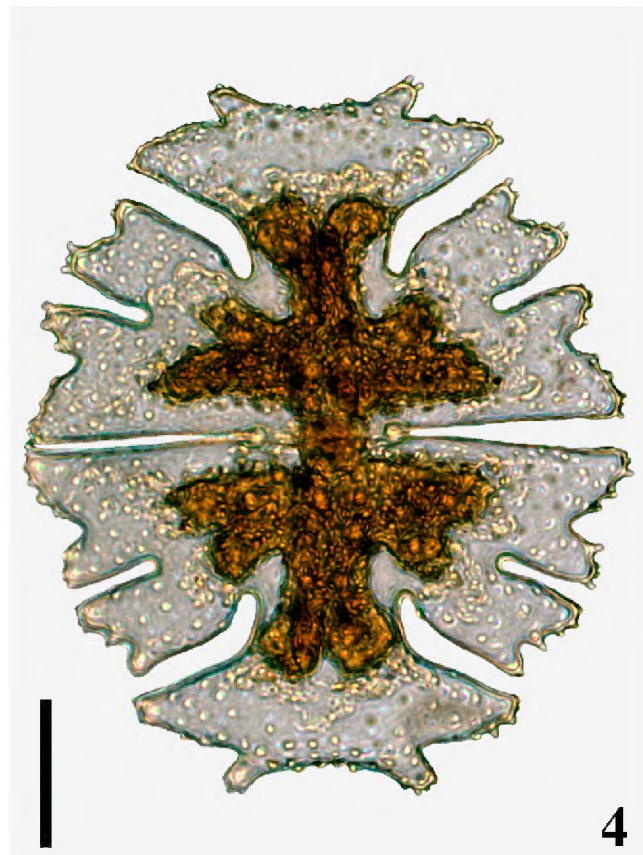
Figure 4

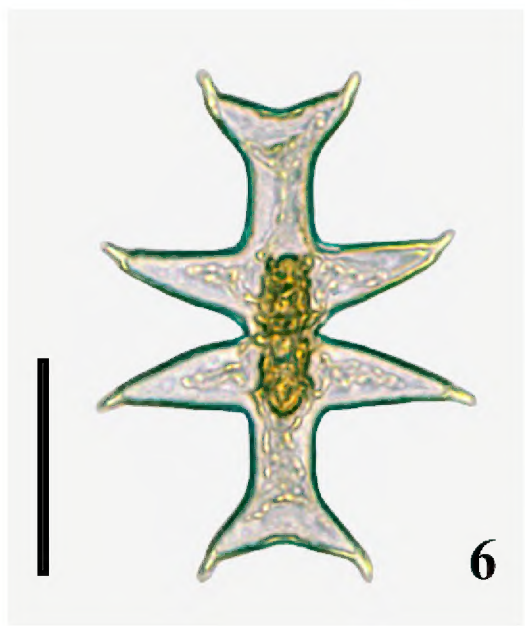
Material examined. Brazil, Bahia, Camaçari, APA Lagoas de Guarajuba, 25/VIII/2007, I.B. Oliveira, I.S. Oliveira and T.B. Oliveira, s/n. (HUEFS 125619) (material type).

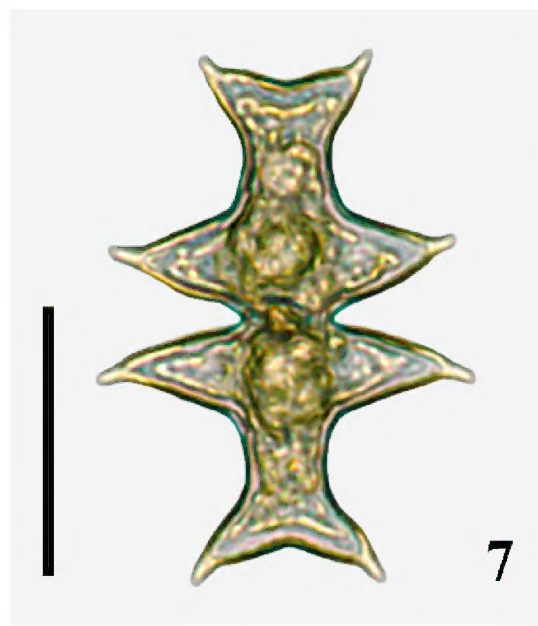
Notes. *Micrasterias americana* var. *bahiensis* was newly described by Oliveira et al. (2009) from material collected in the municipality of Camaçari, and through the reanalysis of the type material, we note that it is morphologically close to *Micrasterias americana* (Ehrenb.) Ralfs var. *boldtii* Gutw. These 2 varieties differ by the morphology of the polar lobe, which is narrower in the former, with sharper ends and rectilinear or slightly concave inferior margins, while in the latter it is wider with more inflated extremities and slightly convex inferior











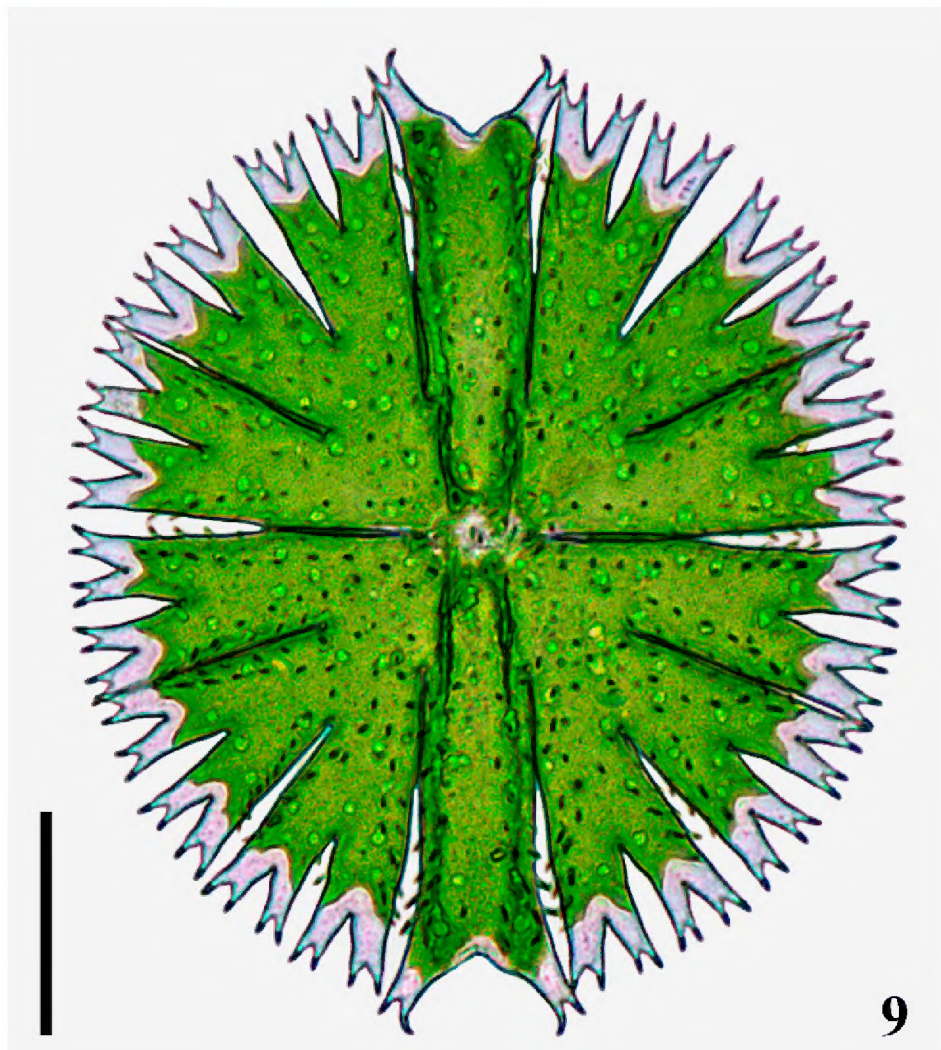


Figure 2–10. *Micrasterias* from Metropolitan Region of Salvador. **2.** *Micrasterias abrupta* var. *abrupta*. **3.** *Micrasterias alata* var. *alata*. **4.** *Micrasterias americana* var. *bahiensis*. **5.** *Micrasterias arcuata* var. *arcuata*. **6.** *Micrasterias arcuata* var. *expansa*. **7.** *Micrasterias arcuata* var. *robusta*. **8.** *Micrasterias arcuata* var. *subpinnatifida*. **9.** *Micrasterias borgei* var. *borgei*. **10.** *Micrasterias denticulata* var. *denticulata*. Scale bars: Figs 2, 4, 5–8 = 30 µm; Figs 3, 9, 10 = 60 µm.

Table 2. Occurence and categories of frequency of *Micrasterias* taxa by Metropolitan Region of Salvador (MRS) Municipalities, Bahia, Brazil. CA = Camaçari, CN = Candeias, DA = Dias D'Ávila, IT = Itaparica, LF = Lauro de Freitas, MS = Mata de São João, PO = Pojuca, SA = Salvador, SF = São Francisco do Conde, SS = São Sebastião do Passé, VC = Vera Cruz. Categories of frequency: > 70% (quite frequent, VF); ≤ 70% and > 40% (frequent, F); ≤ 40% and > 10% (occasional, O); and ≤ 10% (rare, R); (—) = Absent. (*) = First citation for RMS.

Taxa	Categories of frequency											
	Geral	Municipalities										
	RMS	CA	CN	DA	IT	LF	MS	PO	SA	SF	SS	VC
M. abrupta var. *abrupta*	R	R	R	—	—	—	O	—	O	—	R	R
M. alata var. *alata*	O	F	—	—	—	O	R	—	R	—	—	R
M. americana var. *bahiensis*	R	R	—	—	—	—	—	—	—	—	—	—
M. arcuata var. *arcuata**	R	—	—	—	—	O	—	—	—	—	—	—
M. arcuata var. *expansa*	R	—	—	—	—	O	O	—	—	—	—	—
M. arcuata var. *robusta*	R	—	—	—	—	O	R	—	—	—	—	—
M. arcuata var. *subpinnatifida*	O	O	—	—	—	—	R	—	O	—	—	—
M. borgei var. *borgei*	R	R	O	—	—	O	O	O	—	—	O	R
M. denticulata var. *denticulata*	R	—	—	—	—	—	R	—	—	—	—	—
M. foliacea var. *foliacea*	R	O	—	—	—	—	R	—	—	—	—	O
M. furcata var. *furcata*	O	O	—	—	—	—	O	—	O	F	—	O
M. furcata var. *dichotoma*	R	—	—	—	—	—	—	—	—	—	—	R
M. laticeps var. *laticeps*	O	R	O	VF	—	O	O	VF	O	F	F	O
M. laticeps var. *acuminata*	O	R	F	VF	—	O	R	O	F	F	F	—
M. laticeps var. *ampliata*	R	—	—	—	—	—	R	—	—	—	—	—
M. mahabuleshwarensis var. *mahabuleshwarensis*	R	VF	—	—	—	—	R	—	—	O	—	R
M. mahabuleshwarensis var. *ampullacea*	R	VF	—	—	—	—	—	—	—	O	—	—
M. papillifera var. *glabra*	R	—	—	—	—	—	R	—	—	—	—	—
M. pinnatifida var. *pinnatifida*	F	VF	—	F	F	O	F	VF	VF	—	O	O
*M. quadridentata**	R	—	—	—	—	—	R	—	—	—	—	—
M. radians	R	R	—	—	VF	F	R	O	O	—	—	F
M. radiosa var. *radiosa*	R	R	O	—	—	O	O	O	O	O	R	R
M. radiosa var. *elegantior*	O	F	—	—	—	—	R	O	—	—	O	R
M. radiosa var. *ornata* f. *ornata*	R	R	O	—	—	—	R	O	O	O	O	R
M. radiosa var. *ornata* f. *aculeata*	R	—	—	—	—	—	R	O	R	—	—	R
M. rotata var. *rotata*	R	R	—	—	F	O	R	—	O	—	—	O
M. thomasiana var. *notata*	R	—	—	—	—	—	R	—	—	—	—	O
M. torreyi var. *nordestedtiana**	R	—	—	—	—	—	—	O	—	O	—	—
M. truncata var. *pusilla*	O	F	O	—	—	VF	O	O	F	F	F	—
Total	**29**	**18**	**7**	**2**	**3**	**12**	**24**	**11**	**13**	**9**	**9**	**16**

margins. *Micrasterias americana* var. *bahiensis* occurred only in Camaçari, where it had a frequency of occurrence of < 10% (Table 2).

***Micrasterias arcuata* Bailey var. *arcuata*, 1851**
Figure 5

Material examined. Brazil, Bahia, Lauro de Freitas, Catu de Abrantes, 2/X/2015, C.A. Ribeiro, C.W.N. Moura and G.J.P. Ramos, s/n. (HUEFS 219846).

Notes. *Micrasterias arcuata* var. *arcuata* is similar to *M. arcuata* Bailey var. *subpinnatifida* Nordstedt, although the 2 varieties can be distinguished by the curvature of the basal lobes, which are parallel to the polar lobe in var. *subpinnatifida* and curved towards the apical lobe in the typical variety. In Bahia, it has been cited for Chapada Diamantina (Förster 1964) and for the municipalities of Conde, Esplanada, and Entre Rios (Oliveira 2011). *Micrasterias arcuata* var. *arcuata* is rare in the MRS, having been found in only 1 sample unit. Ours is the first record of *M. arcuata* var. *arcuata* from the MRS (Table 2).

***Micrasterias arcuata* Bailey var. *expansa* (Bailey) Nordstedt, 1877**
Figure 6

Material examined. Brazil, Bahia, Lauro de Freitas, Catu de Abrantes, 2/X/2015, C.A. Ribeiro, C.W.N. Moura and G.J.P. Ramos, s/n. (HUEFS 219846); Mata de São João, Jauara Lagoon, 14/VII/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219766).

Notes. *Micrasterias arcuata* Bailey var. *expansa* differs from the typical variety because it has subcunate apical lobe that is always smaller than the set of basal lobes, an apical margin that always has a slight median depression and extremities with divergent spines (Sormus 1980, Oliveira 2017). This variety has a restricted distribution in Brazil, with records only for 3 states: Bahia (Oliveira et al. 2017), Minas Gerais (Nordstedt 1877), and São Paulo (Borge 1918). It is rare in the MRS but is occasional in the municipalities of Lauro de Freitas and Mata de São João (Table 2).

***Micrasterias arcuata* Bailey var. *robusta* Borge, 1899**
Figure 7

Material examined. Brazil, Bahia, Lauro de Freitas, Catu de Abrantes, 02/X/2015, C.A. Ribeiro et al. s/n. (HUEFS 219846); Mata de São João, Jauara Lagoon, 14/VII/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219766).

Notes. *Micrasterias arcuata* Bailey var. *robusta* is very similar to *M. arcuata* var. *expansa* from which it differs by having shorter cell lobes and inflated basal lobes. We observed no significant morphological variation, but compared to the material from São Paulo described by Bicudo and Sormus (1982), the specimens from MRS have a slightly narrower polar lobe. The variety had a frequency of occurrence of < 10% in the MRS, and we classified it as rare (Table 2).

Micrasterias arcuata Bailey var. *subpinnatifida* West & G.S.West, 1897

Figure 8

Material examined. Brazil, Bahia, Camaçari, Cetrel, 02/II/2015, M.A. Santos et al. s/n. (HUEFS 219835); Mata de São João, Aruá Lagoon, 01/IX/2014, M.A. Santos et al. s/n. (HUEFS 219786); Salvador, Av. Paralela, 31/III/2014, C.W.N. Moura et al. s/n. (HUEFS 219749).

Notes. The variety is easily recognizable by its 3-lobed semicells and "T"-shaped apical lobe with acuminate extremities. It resembles and may even be mistaken for *Micrasterias arcuata* Bailey var. *subcornuta* Förster, from which it differs only in the ornamentation of the zygosporum cell wall, which in var. *subcornuta* has papillae (Bicudo and Sormus 1982). Although we did not observe the zygospore, we chose to identify our material as *M. arcuata* var. *subpinnatifida* because it has measurements consistent with that variety; that is, twice the size recorded for *M. arcuata* var. *subcornuta*. In addition, it has the "T"-shaped apical lobe and semicells with basal lobes parallel to each possessed by *M. arcuata* var. *subpinnatifida*. This variety was recorded in about 23% of the samples analyzed in the MRS, and we consider it to be occasional in the MRS (Table 2).

Micrasterias borgei W.Krieger var. *borgei*, 1939

Figure 9

Material examined. Brazil, Bahia: Camaçari, APA Lagoas de Guarajuba, 25/VIII/2007, I.B. Oliveira et al. s/n. (HUEFS 125621); Candeias, Lagoon - BR 324, 12/IX/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219805); Lauro de Freitas, Catu de Abrantes, 02/X/2015, C.A. Ribeiro et al. s/n. (HUEFS 219847); Mata de São João, Lagoon - BA 512, 14/VII/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219773); Pojuca, Lagoon near to BA-093, 15/XI/2014, M.A. Santos and G.J.P. Ramos, a/no. (HUEFS 219816); São Sebastião do Passé, Canabrava, 08/IX/2014, M.A. Santos et al. s/n. (HUEFS 219794); Vera Cruz, Lagoon near to BA-532, 23/VII/2015, M.A. Santos and C.A. Ribeiro s/n. (HUEFS 219233).

Notes. Analysis of the literature revealed that this species can vary with regard to the projection of the polar lobe, morphology of the lateral and basal lobes, and quantity and arrangement of the spines on the cellular wall. *Micrasterias borgei* var. *borgei* and *M. rotata* var. *rotata* may be visually similar; however, the separation between them is made through the ornamentation of the cell wall, as *M. borgei* presents robust spines distributed all over the face of the cell, different from *M. rotata*, which has a smooth cell wall. *M. borgei* var. *borgei* can also present some resemblance to the varieties of *M. radiosa* studied, but unlike *M. borgei* var. *borgei*, all varieties of *M. radiosa* here identified have lateral and basal lobes of sizes same, broadly deep cell incisions, and polar lobe with 2 or more spines. As with Santos et al. (2016), who observed specimens from Itaparica Island, the populations analyzed here from other municipalities of the MRS exhibited variation only in the morphology of the lateral and basal lobes, which were sometimes similar to each other or sometimes unequal, but the lateral lobes were always larger than the basal lobes. In Brazil, *M. borgei* var. *borgei* occurs in both phytoplankton and periphyton and has been recorded in environments with low pH values (Melo et al. 2009, Menezes et al. 2011). Although *M. borgei* var. *borgei* is widely distributed in the MRS, occurring in seven of the 11 municipalities studied, it presented a low frequency of occurrence (Table 2).

Micrasterias denticulata Brébisson ex Ralfs var. *denticulata*, 1848

Figure 9

Material examined. Brazil, Bahia, Mata de São João, Praia do Forte, 26/VII/2009, I.B. Oliveira and J.T. Farias, s/n. (HUEFS 155787).

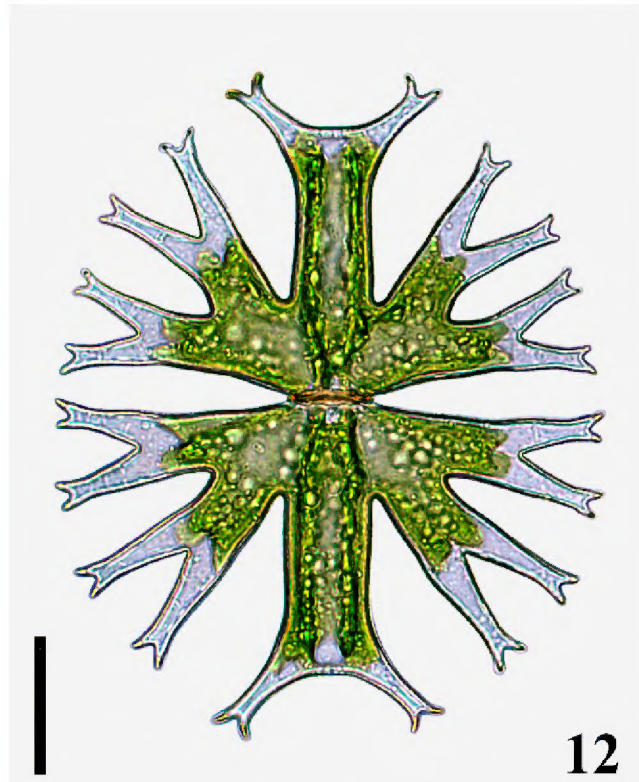
Notes. *Micrasterias denticulata* var. *denticulata* is easily identified by the presence of similar lateral and basal lobes, linear and closed cell incisions, and lobules of the last order with rectilinear extremities possessing small denticles. According to Šťastný (2010), the species is usually found composing the periphyton of mesotrophic and acidic (pH < 6.5) environments in European lakes. In Brazil, however, it has been reported occurring in both periphyton and phytoplankton (Aquino et al. 2014). We consider it rare in the study area, because it was found in only 2 of our 275 samples (Table 2).

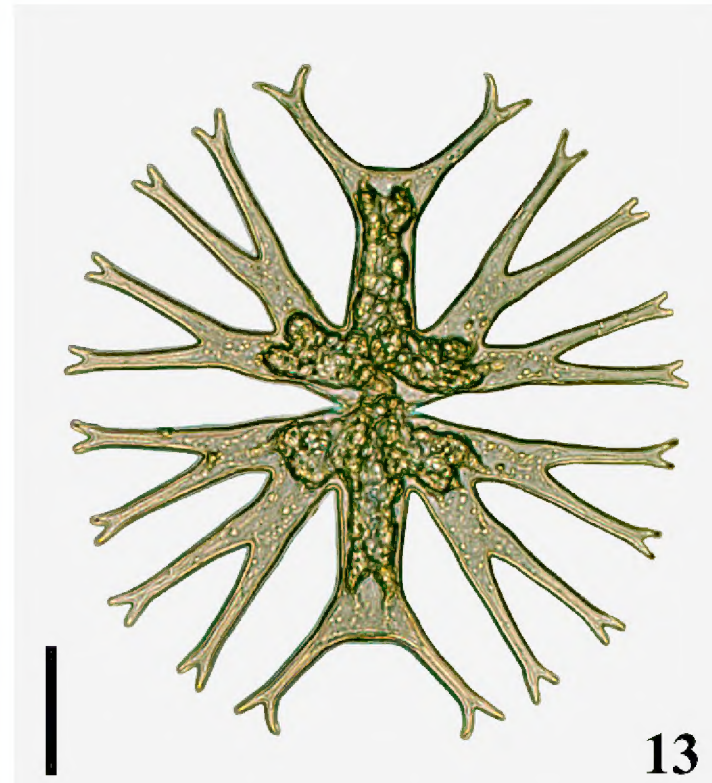
Micrasterias foliacea Bailey ex Ralfs var. *foliacea*, 1848

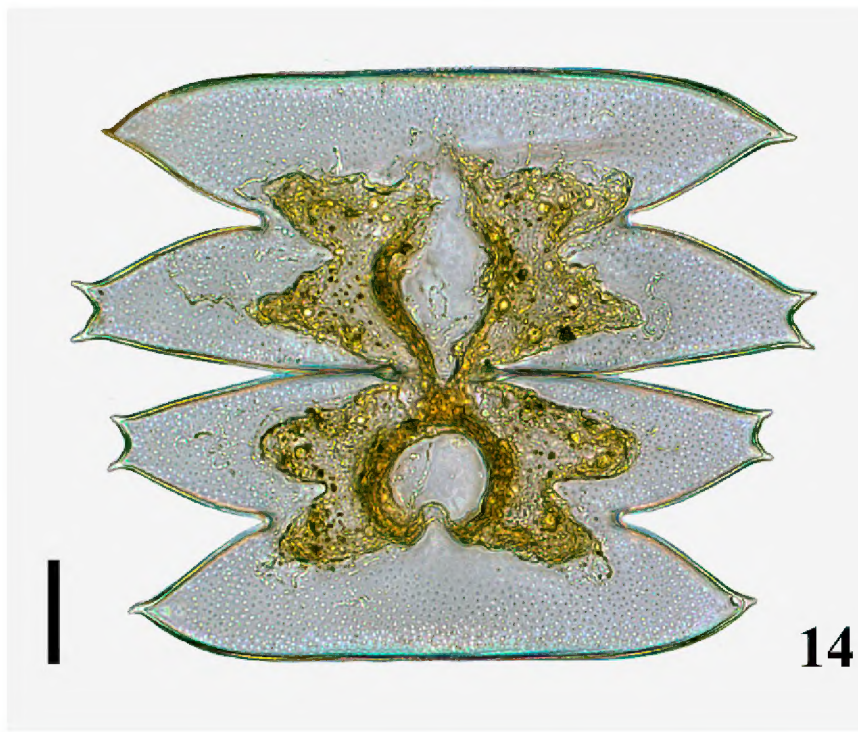
Figure 11

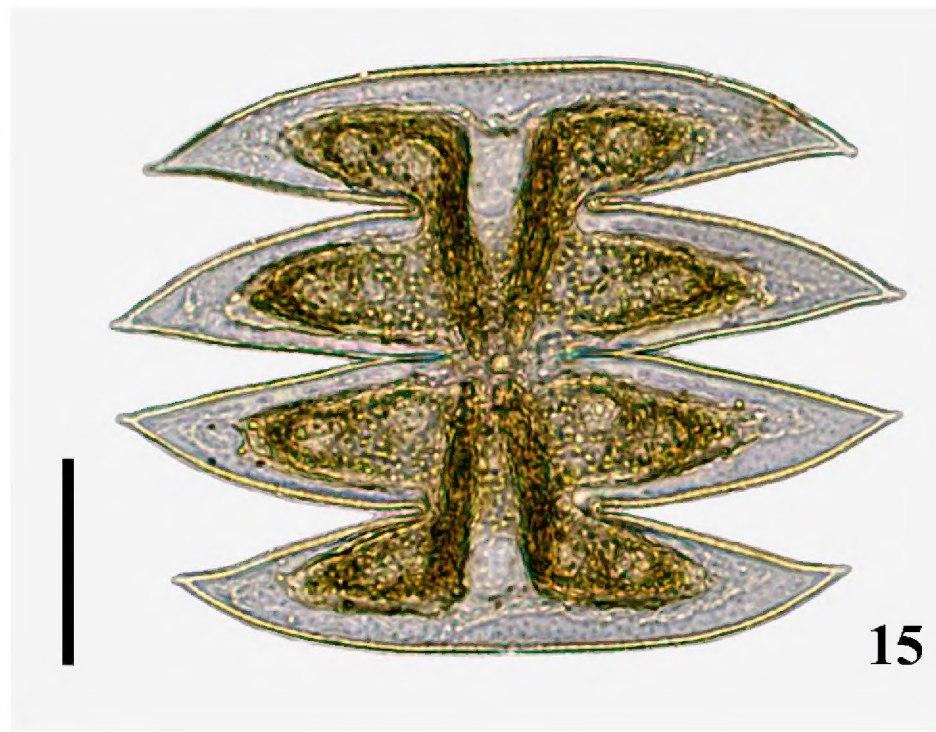
Material examined. Brazil, Bahia, Camaçari, Rio Capivara, 25/VIII/2007, I.B. Oliveira et al. s/n. (HUEFS 125609); Mata de São João, Rio Imbassaí, 14/II/2009, I.B. Oliveira and C.W.N. Moura, s/n. (HUEFS 155623); Vera Cruz, Estrada Porcaozinho, 25/VIII/2014, M.A. Santos et al. s/n. (HUEFS 219213).

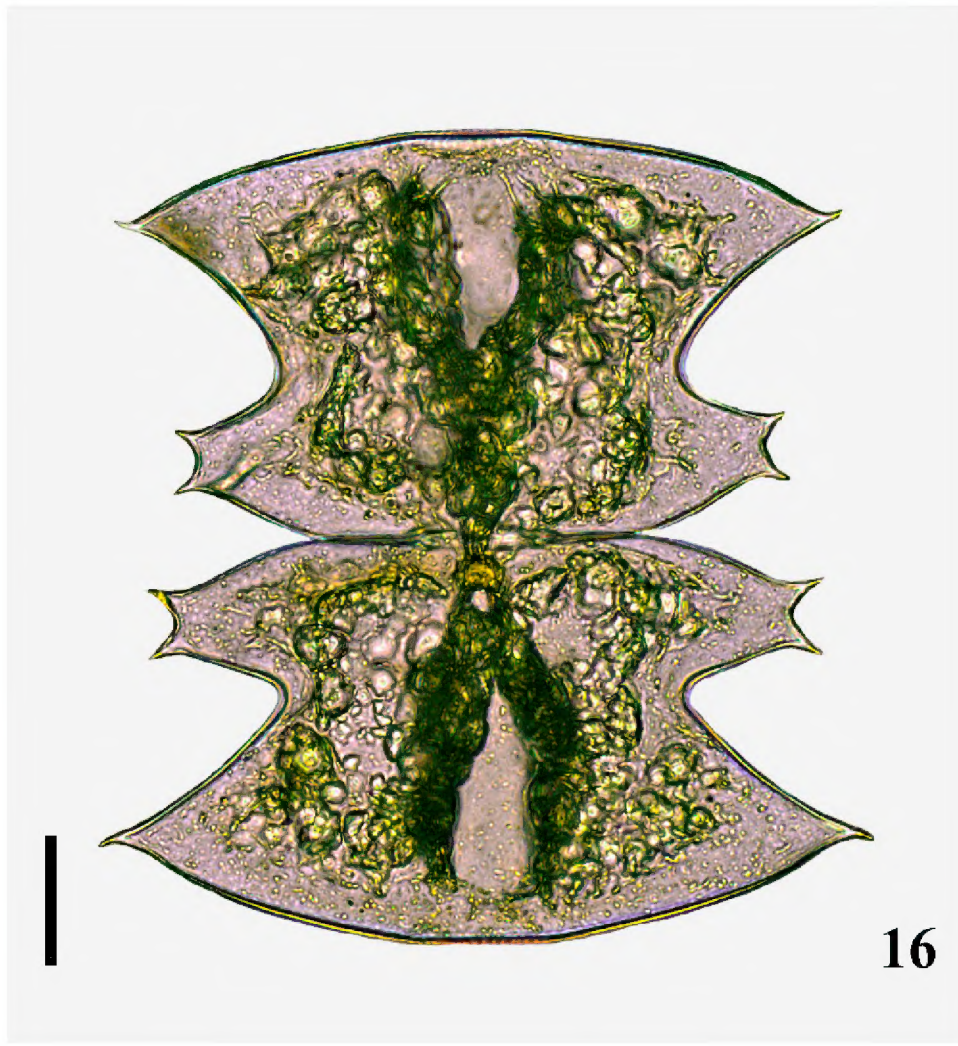
Notes. This is the species of the genus whose cells are











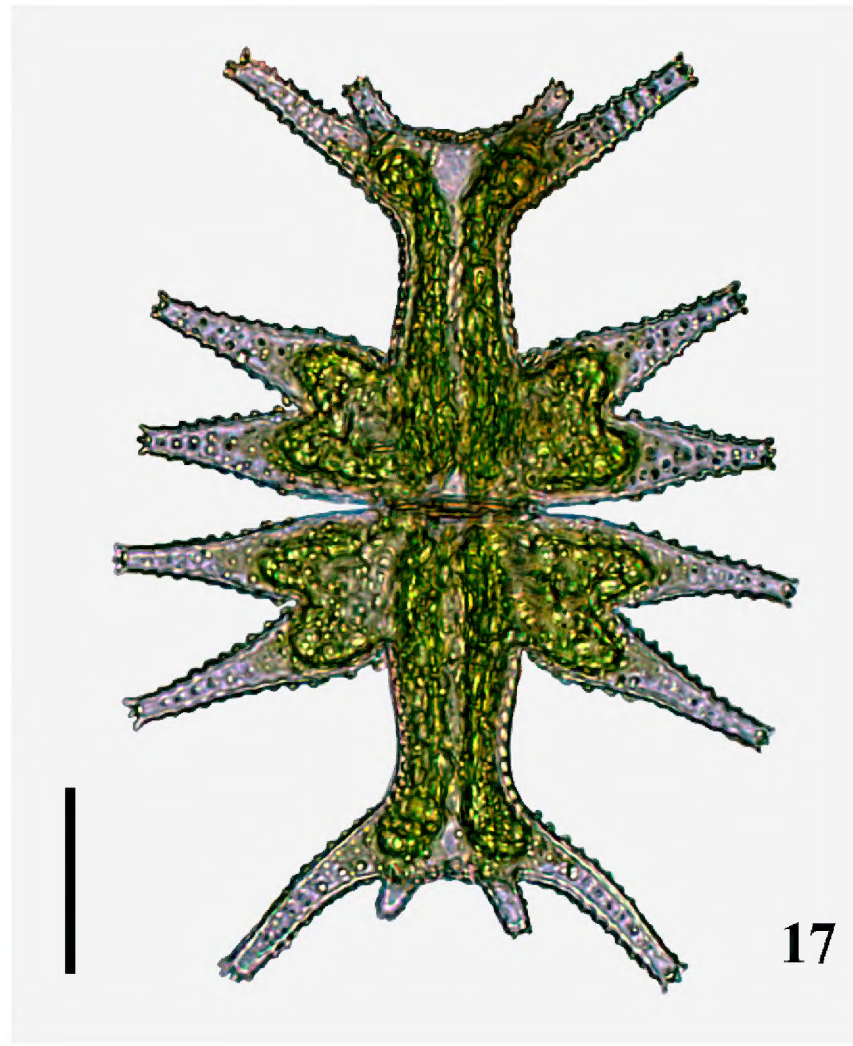


Figure 11–17. *Micrasterias* from Metropolitan Region of Salvador. **11.** *Micrasterias foliacea* var. *foliacea*. **12.** *Micrasterias furcata* var. *furcata*. **13.** *Micrasterias furcata* var. *dichotoma*. **14.** *Micrasterias laticeps* var. *laticeps*. **15.** *Micrasterias laticeps* var. *acuminata*. **16.** *Micrasterias laticeps* var. *ampliata*. **17.** *Micrasterias mahabuleshwarensis* var. *mahabuleshwarensis*. Scale bars = 30 µm.

united in pseudofilaments, which makes it easy to recognize (Ribeiro et al. 2015). In the MRS, we recorded it in the municipalities of Camaçari, Mata de São João, and Vera Cruz. No morphological variation was observed in these populations. This taxon occurred in approximately 10% of our samples, and thus we classified it as rare in the MRS (Table 2).

Micrasterias furcata C. Agardh *ex* Ralfs var. *furcata*, 1848

Figure 12

Material examined. Brazil, Bahia, Camaçari, Lagoas de Guarajuba, 20/VII/2007, I.B. et al. s/n. (HUEFS 125592); Mata de São João, Lagoon - BA 512, 14/VII/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219773); Salvador, Vitória Lagoon, 16/VIII/2014, M.A. Santos et al. s/n. (HUEFS 219777); São Francisco do Conde, Lagoon near to BA-523, 15/V/2014, M.A. Santos and A.A. Santos, s/n. (HUEFS 219754); Vera Cruz, Estrada Porcaozinho, 25/VIII/2014, M.A. Santos et al. s/n. (HUEFS 219214).

Notes. This taxon is widely distributed in Brazil, with records for all regions of the country (Araújo et al. 2015). In Brazil, there are reports of its occurrence in phytoplankton (Bortolini et al. 2010) and periphyton (Camargo et al. 2009) of rivers, and in bromeliad phytotelmata environments (Ramos et al. 2011). In the MRS, we found it occasionally in approximately 17% of our samples (Table 2).

Micrasterias furcata var. *dichotoma* (Wolle) Růžička, 1980

Figure 13

Material examined. Brazil, Bahia, Vera Cruz, Estrada Porcaozinho, 15/II/2015, M.A. Santos and G.J.P. Ramos s/n. (HUEFS 219224).

Notes. Despite the strong similarity with the typical variety, *Micrasterias furcata* var. *dichotoma* is distinct because it possesses narrower lobes and lobules, distinctly deeper cell incisions, and a polar lobe with a more open concavity (Santos et al. 2016). We consider this variety to be rare in the MRS, occurring in only 1% of our samples (Table 2).

Micrasterias laticeps Nordstedt var. *laticeps*, 1869

Figure 14

Material examined. Brazil, Bahia, Camaçari, Rio Capivara, 20/VII/2007, I.B. Oliveira et al. s/n. (HUEFS 125584); Candeias, Lagoon - BR 324, 12/IX/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219805); Dias D'Ávila, Rio Jacuípe, 22/XI/2014, M.A. Santos et al. s/n. (HUEFS 219823); Lauro de Freitas, Jardim Primavera, 26/I/2015, M.A. Santos, s/n. (HUEFS 219831); Mata de São João, Imbassaí, 11/I/2009, I.B. Oliveira et al. s/n. (HUEFS 155605); Pojuca, Lagoon - BR 420, 08/IX/2014, M.A. Santos et al. s/n. (HUEFS 219799); Salvador, Lagoon near to FTC, 13/XII/2014, M.A. Santos, s/n. (HUEFS 219827); São Francisco do Conde, Lagoon - BA 523, 15/V/2014, M.A. Santos and A.A. Santos, s/n. (HUEFS 219754); São Sebastião do Passé, Canabrava, 08/IX/2014, M.A. Santos et al. s/n. (HUEFS 219794); Vera Cruz, Estrada Porcaozinho, 05/II/2015, M.A. Santos and G.J.P. Ramos s/n. (HUEFS 219222).

Notes. The species is known to be polymorphic, varying mainly in the width and curvature of the polar lobe and opening of the interlobular incisions (Santos et al. 2016, Moresco et al. 2009). It has a wide occurrence in Brazil (Araújo et al. 2015), being reported for both phytoplankton and periphyton (Felisberto and Rodrigues 2005, Melo et al. 2005). In the MRS, it was the most represented taxon, recorded from 10 of the 11 municipalities sampled. We classify it as rare only in the municipality of Camaçari (Table 2).

Micrasterias laticeps Nordstedt var. *acuminata* W.Krieger, 1939

Figure 15

Material examined. Brazil, Bahia: Camaçari, Lagoas de Guarajuba, 12/I/2007, I.B. Oliveira and I.S. Oliveira, s/n. (HUEFS 125509); Candeias, Lagoon - BR 324, 12/IX/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219805); Dias D'Ávila, Rio Jacuípe, 22/XI/2014, M.A. Santos et al. s/n. (HUEFS 219823); Lauro de Freitas, Jardim Primavera, 26/I/2015, M.A. Santos, s/n. (HUEFS 219831); Mata de São João, Rio Açu, 16/V/2014, M.A. Santos and G.J.P. Ramos, n/no. (HUEFS 219760); Pojuca, Lagoon near to BA-093, 15/XI/2014, M.A. Santos and G.J.P. Ramos, a/no. (HUEFS 219816); Salvador, Parque De Pituaçu, 13/VII/2014, M.A. Santos et al. s/n. (HUEFS 219828); São Francisco do Conde, Lagoon- BA 522, 15/VII/2014, M.A. Santos et al. s/n. (HUEFS 219775); São Sebastião do Passé, Fazenda Caípe, 15/XI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219812).

Notes. *Micrasterias laticeps* var. *acuminata* differs from the typical variety of the species because it possesses acuminate instead of 2-denticulate basal lobes. In the literature, the main morphological variation described for *M. laticeps* var. *acuminata* is with the interlobular incisions, which may be shallow or deep and with an acutangular or rounded vertex; however, in the studied populations such variation was not observed. *Micrasterias laticeps* var. *acuminata* has a wide geographic distribution, occurring in all regions of Brazil, both in plankton and periphyton from oligotrophic to acidic (pH < 5.9) mesotrophic environments (Camargo et al. 2009, Aquino et al. 2014, Araújo et al. 2015, Silva and Felisberto 2015). Although we recorded this variety in most of the municipalities of the MRS, it occurred in only 12% of our samples, and thus, we considered it to be occasional (Table 2).

Micrasterias laticeps Nordstedt var. *ampliata* W.Krieger, 1939

Figure 16

Material examined. Brazil, Bahia, Mata de São João, Imbassaí, 11/I/2009, I.B. Oliveira and C.W.N. Moura, s/n. (HUEFS 155610).

Notes. *Micrasterias laticeps* var. *ampliata,* unlike the typical variety of the species, has the face of the semicell inflated, apical lobe wider than the set of basal lobes, and ends of the polar lobe with single spines, which always face upwards. In Bahia, this taxon has been recorded for Chapada Diamantina (Förster 1964) and for Mata de São João (Oliveira 2011). *Micrasterias laticeps* var. *ampliata* was found in only 3 of our 275 samples, which reflects its low frequency of occurrence in the MRS (Table 2).

***Micrasterias mahabuleshwarensis* J.Hobson var. *mahabuleshwarensis*, 1863**
Figure 17

Material examined. Brazil, Bahia, Camaçari, Rio Capivara, 12/I/2007, I.B. Oliveira and I.S. Oliveira, s/n. (HUEFS 125514); Mata de São João, Imbassaí, 26/VII/2009, I.B. Oliveira and J.T. Farias, s/n. (HUEFS 155776); São Francisco do Conde, Lagoon - BA 523, 15/V/2014, M.A. Santos and A.A. Santos, s/n. (HUEFS 219754); Vera Cruz, Lagoon BA-001, 23/VII/2015, M.A. Santos and C.A. Ribeiro s/n. (HUEFS 219234).

Notes. This species can exhibit variation in the projection of the lateral and basal lobes, concavity of the polar lobe, and the presence or absence of supraisthmal facial decoration (Růžička 1981, Ribeiro et al. 2015, Silva and Felisberto 2015). In the samples from the MRS, the most varied character in the study specimens was the projection of the lateral and basal lobes, which were mostly projected horizontally rather than diagonally. Although this species is commonly recorded in periphyton (Felisberto and Rodrigues 2005, 2008, Camargo et al. 2009), there are also reports of its occurrence in plankton (Melo et al. 2005). In the MRS we consider it to be rare (Table 2).

***Micrasterias mahabuleshwarensis* J. Hobsen var. *ampullacea* (W.M.Maskell) Nordstedt, 1888**
Figure 18

Material examined. Brazil, Bahia: Camaçari, Rio Capivara, 12/I/2007, I.B. Oliveira and I.S. Oliveira, s/n. (HUEFS 125514); São Francisco do Conde, Lagoon BA-523, 15/V/2014, M.A. Santos and A.A. Santos, s/n. (HUEFS 219754).

Notes. Morphologically, *Micrasterias mahabuleshwarensis* var. *ampullacea* differs from the typical variety of the species in possessing inflated lateral and basal lobes and a completely serrated cellular contour, which makes its identification relatively easy (Oliveira 2011). In the MRS, this variety was considered rare, occurring only in the municipalities of Camaçari and São Francisco do Conde (Table 2).

***Micrasterias papillifera* Brébisson ex Ralfs var. *glabra* Nordstedt, 1882**
Figure 19

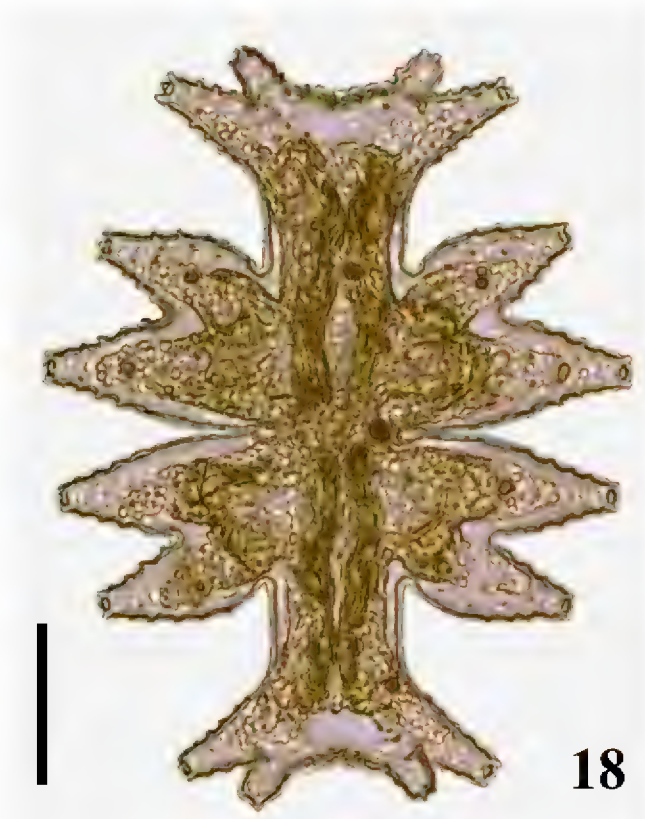
Material examined. Brazil, Bahia: Mata de São João, Rio Açu, 26/VII/2009, I.B. Oliveira and J.T. Farias, s/n. (HUEFS 155781).

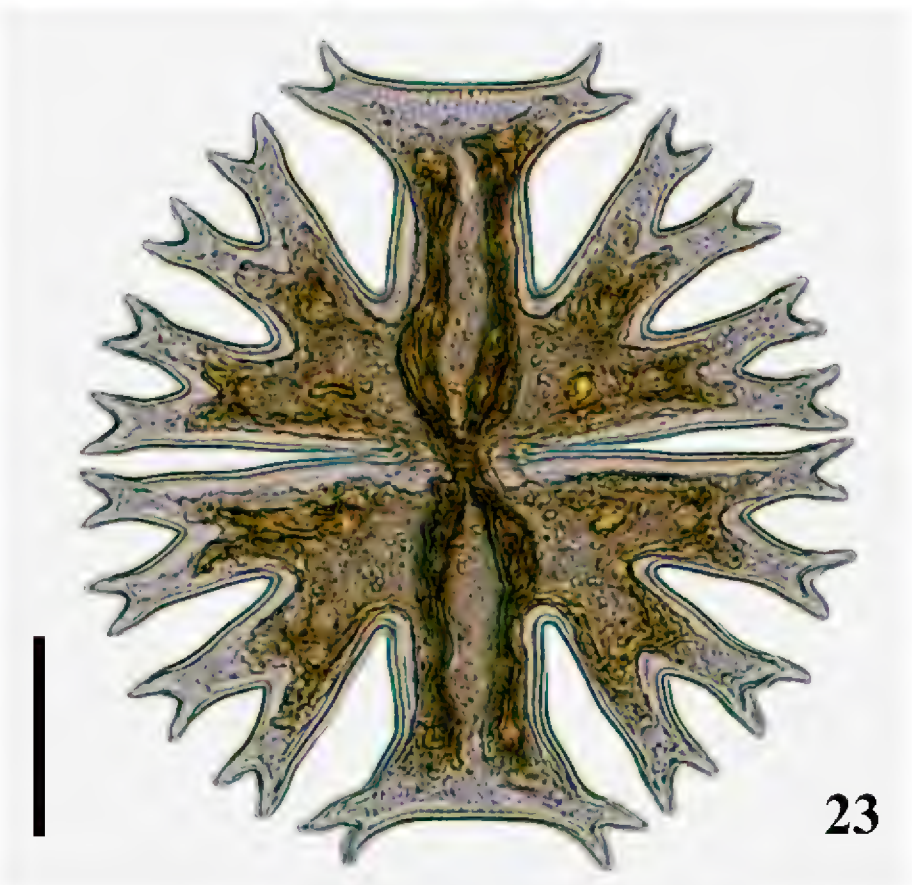
Notes. *Micrasterias papillifera* var. *glabra* is morphologically similar to *M. novae-terrae* (Cushm.) Krieger. However, it has a subelliptic cellular contour, a larger lateral lobe than basal lobe, and open cellular incisions. In the MRS, samples had both individuals with the typical morphology of *M. papillifera* var. *glabra* and morphologically differentiated individuals with a subelliptic cellular contour, open cellular incisions, and basal lobes somewhat smaller than lateral lobes, which approach *M. novae-terrae* var. *novae-terrae* in morphology. Despite this similarity, we chose to identify such individuals as *M. papillifera* var. *glabra* because they possess all the other characteristics used to delimitate the species and because we observed, among our specimens, that the basal lobe always subdivides into lobules of the second or third order, instead of only lobules of the first order, as usually occurs in *M. novae-terrae*. We consider *M. papillifera* var. *glabra* rare in the MRS (Table 2).

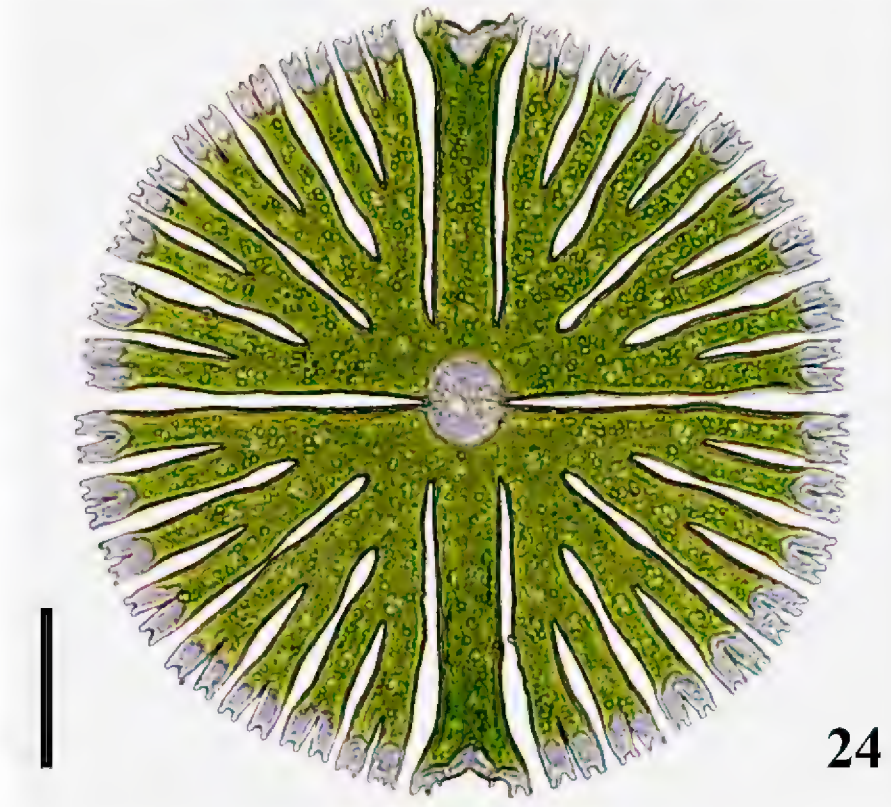
***Micrasterias pinnatifida* (Kützing) Ralfs var. *pinnatifida*, 1848**
Figures 20, 21

Material examined. Brazil, Bahia: Camaçari, APA Lagoas de Guarajuba, 25/VIII/2007, I.B. Oliveira et al. s/n. (HUEFS 125621); Itaparica, Engenho, 23/II/2015, M.A. Santos and C.A. Ribeiro s/n. (HUEFS 219231); Lauro de Freitas, Catu de Abrantes, 02/X/2015, C.A. Ribeiro et al. s/n. (HUEFS 219847); Mata de São João, Jauara Lagoon, 14/VII/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219765); Pojuca, Lagoon BR-420, 08/IX/2014, M.A. Santos et al. s/n. (HUEFS 219799); Salvador, Vitória Lagoon, 16/VIII/2014, M.A. Santos et al. s/n. (HUEFS 219778); São Sebastião do Passé, Santo André, 15/XI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219815); Vera Cruz, Lagoon BA-868, 25/VIII/2014, M.A. Santos et al. s/n. (HUEFS 219217).

Notes. The literature reveals that *M. pinnatifida* var. *pinnatifida* is a common taxon in floristic inventories in Brazil. Although it is easy to identify, studies report that it is highly polymorphic, including one study dedicated to the observation of its polymorphism (Sormus and Bicudo 1974). *Micrasterias pinnatfida* var. *pinnatifida* resembles *M. arcuata* var. *subpinnatifida*, but differs in possessing 2-denticulate lobes instead of 1-denticulate lobes. We observed morphological variation in the apical lobe (width and concavity of the apical margin) and lateral lobes (presence or absence of a spine in the upper margin of the lobes) in the MRS. In European lakes, Šťastný (2010) reported this species in the periphyton of mesotrophic and acidic (pH < 6.5) environments, but in







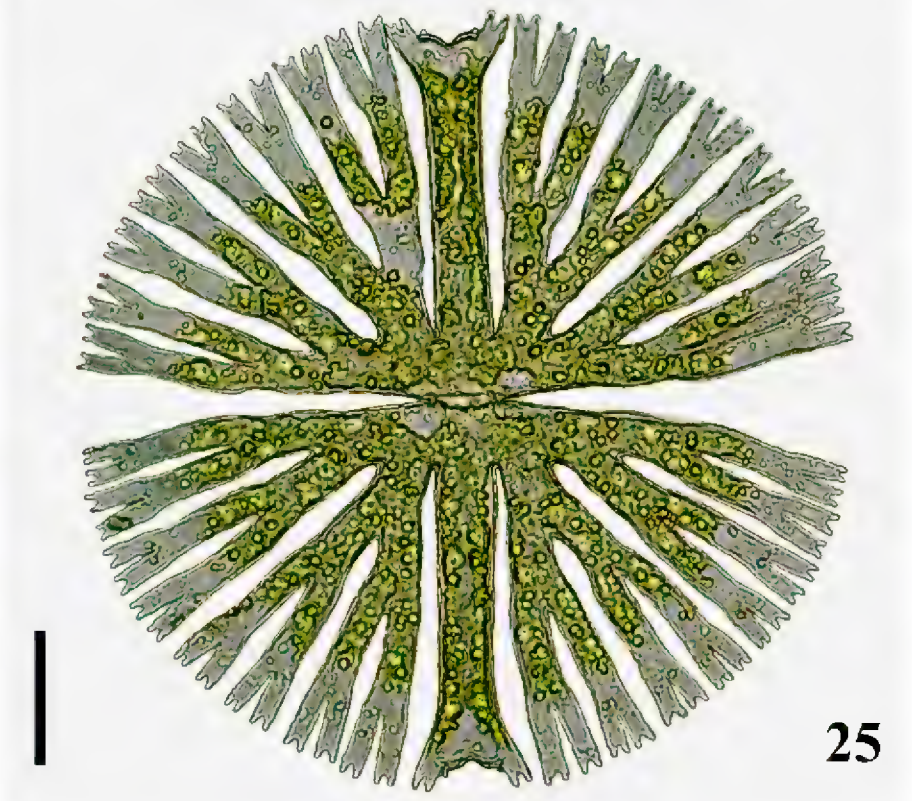


Figure 18–25. *Micrasterias* from Metropolitan Region of Salvador. **18.** *Micrasterias mahabuleshwarensis* var. *ampullacea*. **19.** *Micrasterias papillifera* var. *glabra*. **20, 21.** *Micrasterias pinnatifida* var. *pinnatifida*. **22.** *Micrasterias quadridentata*. **23.** *Micrasterias radians*. **24.** *Micrasterias radiosa* var. *radiosa*. **25.** *Micrasterias radiosa* var. *elegantior*. Scale bars: Figs 18-21, 23–25 = 30 µm; Fig. 22 = 60 µm.

Brazil it has also been recorded in phytoplankton (Melo and Souza 2009). We found *M. pinnatifida* var. *pinnatifida* in 9 of the 11 municipalities studied and consider it to be frequent in the MRS (Table 2).

***Micrasterias quadridentata* (Nordstedt) Grönblad, 1920**
Figure 22

Material examined. Brazil, Bahia: Mata de São João, Jauara Lagoon, 14/VII/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219765).

Notes. *Micrasterias quadridentata* is similar to *M. rotata* var. *rotata* but differs in possessesing a larger cell size, linear and closed cellular incisions, and lobules with the extremities possessing short denticles. The morphology of the lobules can vary, with their ends being rectilinear, or 4-denticulate or, more commonly, 2-denticulate (Bicudo and Sormus 1982, Moresco et al. 2009, Menezes et al. 2013). However, no variation was observed in our study. In Paraná, Menezes et al. (2011) recorded *M. quadridentata* in both the metaphyton and the periphyton of an urban artificial lake. Ours is the first record of this species from the MRS, where we consider it to be rare (Table 2).

***Micrasterias radians* Turner, 1893**
Figure 23

Material examined. Brazil, Bahia, Camaçari, Lagoon near BA-099, 02/II/2015, M.A. Santos et al. s/n. (HUEFS 219839); Itaparica, Engenho, 23/II/2015, M.A. Santos and C.A. Ribeiro s/n. (HUEFS 219231); Lauro de Freitas, Catu de Abrantes, 02/X/2015, C.A. Ribeiro et al. s/n. (HUEFS 219845); Mata de São João, Jauara Lagoon, 14/VII/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219765); Pojuca, Lagoon BR-420, 08/IX/2014, M.A. Santos et al. s/n. (HUEFS 219799); Salvador, Vitória Lagoon, 16/VIII/2014, M.A. Santos et al. s/n. (HUEFS 219780); Vera Cruz, Lagoon near to BA-868, 25/VIII/2014, M.A. Santos et al. s/n. (HUEFS 219210).

Notes. *Micrasterias radians* is morphologically close to *M. furcata* var. *furcata*; however, it is distinct because it possesses a more robust cell, shorter and wider polar lobe, rectilinear to concave apical margin, and extremities terminating in short processes. Although Ramos et al. (2018) observed this species to be fairly polymorphic, we observed no variation in our specimens. This species occurred in 12% of our samples, and thus, we consider it to be occasional (Table 2).

***Micrasterias radiosa* Ralfs var. *radiosa*, 1848**
Figure 24

Material examined. Brazil, Bahia, Camaçari, Lagoon near to Embasa, 22/XI/2014, M.A. Santos et al. s/n. (HUEFS 219821); Candeias, Lagoon BR-324, 12/IX/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219807); Lauro de Freitas, Jardim Primavera, 26/I/205, M.A. Santos, s/n. (HUEFS 219831); Mata de São João, Imbassaí, 11/I/2009, I.B. Oliveira and C.W.N. Moura, s/n. (HUEFS 155610); Pojuca, Lagoon near to BA-093, 15/XI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219816); Salvador, Derba, 27/XI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219825); São Francisco do Conde, Lagoon BA-523, 15/V/2014, M.A. Santos and A.A. Santos, s/n. (HUEFS 219752); São Sebastião do Passé, Santo André, 15/XI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219815); Vera Cruz, Lagoon near to BA-532, 23/VII/2015, M.A. Santos and C.A. Ribeiro s/n. (HUEFS 219233).

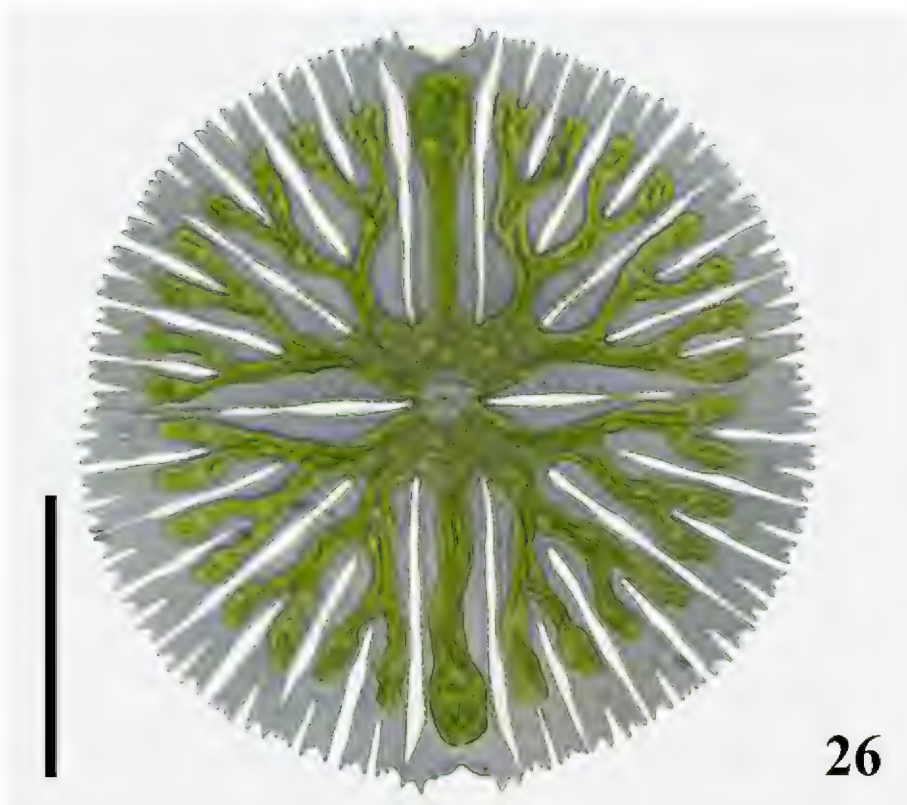
Notes. According to Oliveira et al. (2017), *M. radiosa* var. *radiosa* is easily identified because it possesses circular contouring of the cell, deep incisions, and narrow lobules. However, such characteristics also approximate *M. radiosa* var. *elegantior* (G.S.West) Croasdale, from which it differs by having more robust lobes and deeper and semi-open cellular incisions. According to Bicudo and Sormus (1982), some specimens may have denticles close to the apical notch of the polar lobe, but we did not observe such variation in our specimens. Although we consider it to be rare in the MRS, it was one of the most represented taxa, occurring in 9 of the 11 municipalities studied (Table 2).

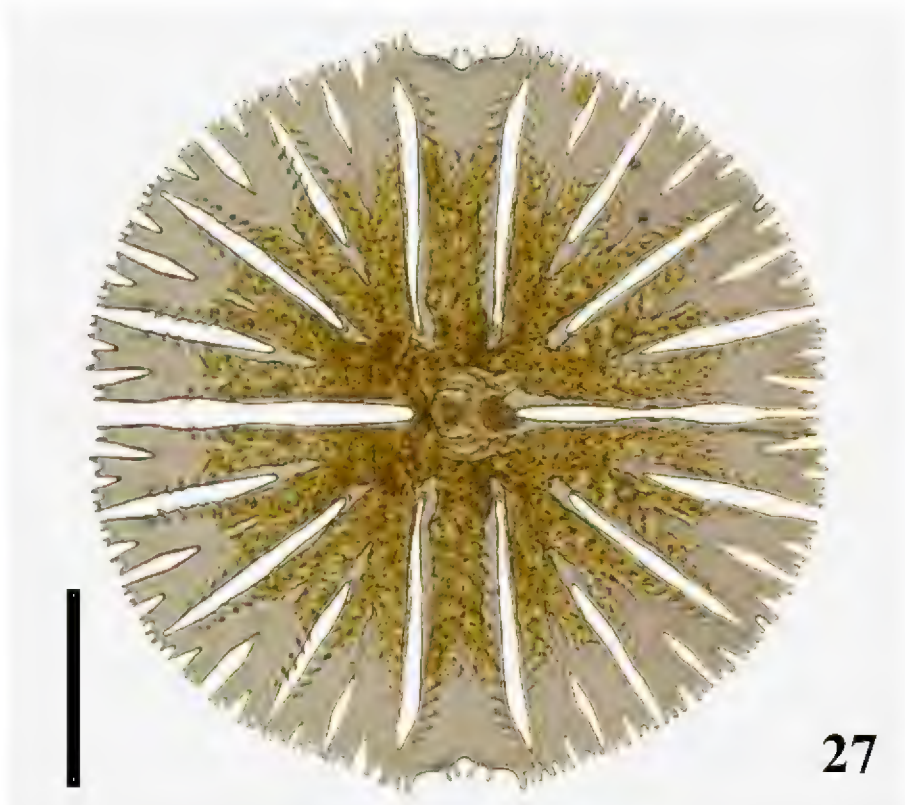
***Micrasterias radiosa* Ralfs var. *elegantior* (G.S.West) Croasdale, 1977**
Figure 25

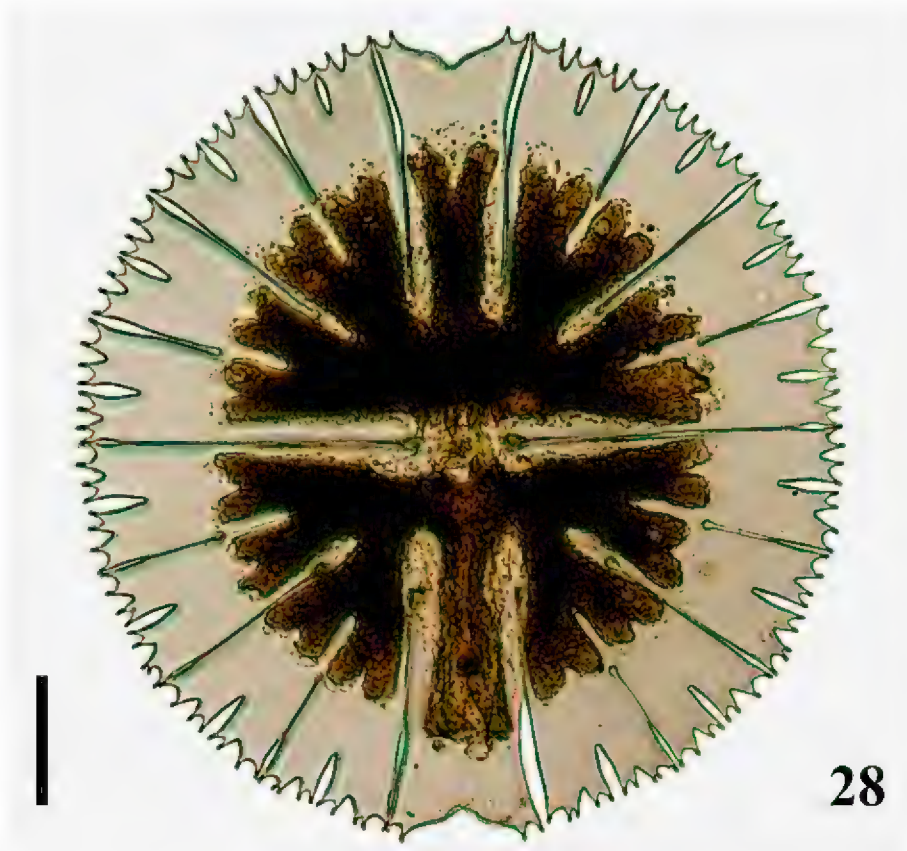
Material examined. Brazil, Bahia, Camaçari, Rio Capivara, 08/VI/2007, I.B. Oliveira et al. s/n. (HUEFS 125568); Mata de São João, Imbassaí, 11/I/2009, I.B. Oliveira and C.W.N. Moura, s/n. (HUEFS 155601); Pojuca, Lagoon near to BA-093, 15/XI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219817); São Sebastião do Passé, Fazenda Caípe, 15/XI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219813); Vera Cruz, Lagoon BA-001, 23/VII/2015, M.A. Santos and C.A. Ribeiro s/n. (HUEFS 219234).

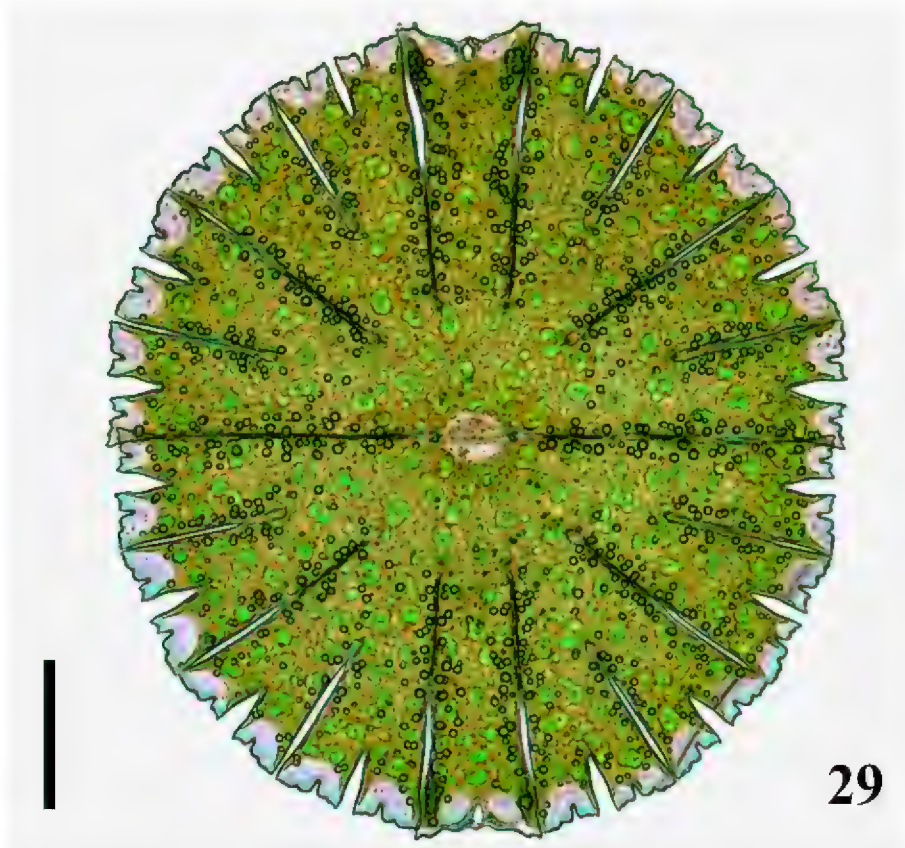
Notes. *Micrasterias radiosa* var. *elegantior* is easily recognized by its narrow lobules and its deep and open incisions. However, identification of this variety requires some care as, according to the literature (Prescott et al. 1977, Bicudo and Sormus 1982) and with our observations, some individuals may possess small spines on the margins of the polar lobe and the median sinus. This brings them closer to *M. radiosa* var. *ornata* f. *ornata*, but this taxon differs by always having a row of spines along the deepest incisions. We found *M. radiosa* var. *elegantior* in 5 municipalities and consider it to be occasional (Table 2).

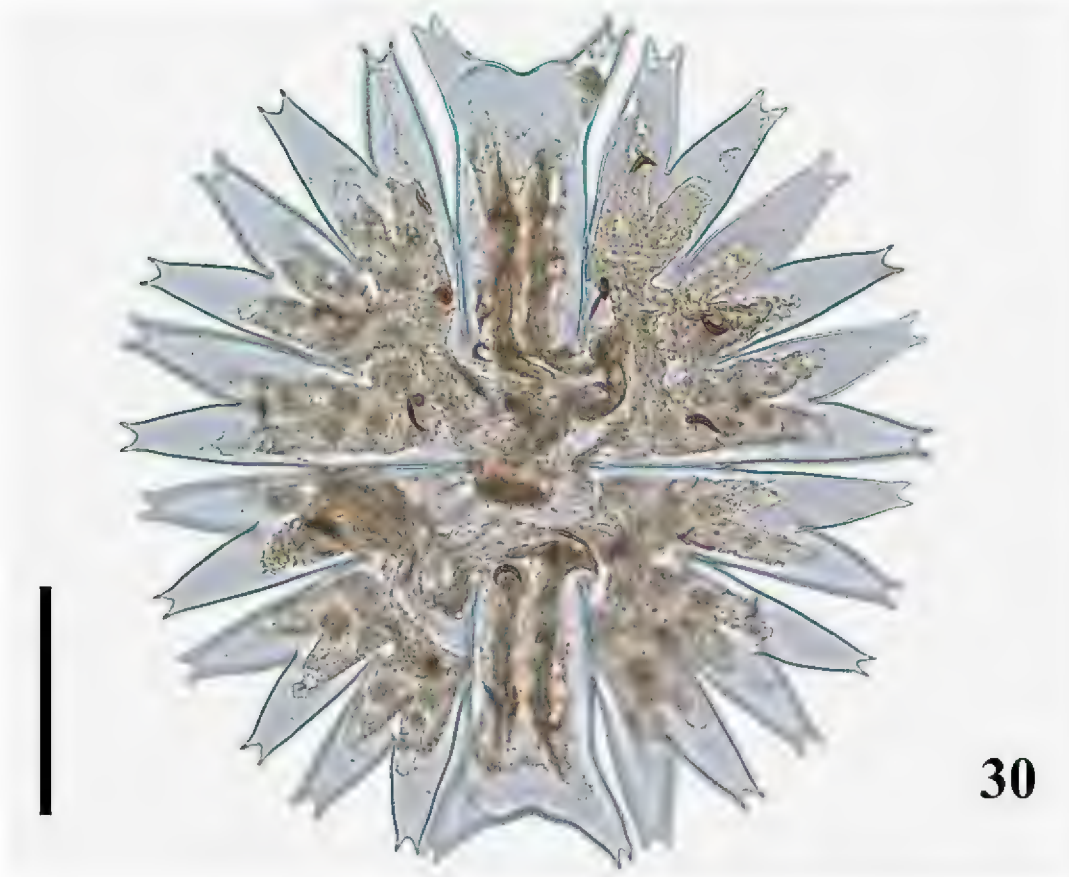
***Micrasterias radiosa* Ralfs var. *ornata* Nordstedt f. *ornata*, 1869**
Figure 26











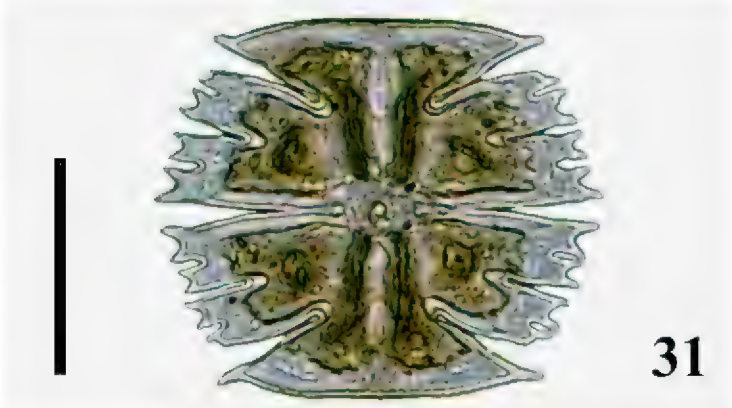


Figure 26–32. *Micrasterias* from Metropolitan Region of Salvador. **26.** *Micrasterias radiosa* var. *ornata* f. *ornata*. **27.** *Micrasterias radiosa* var. *ornata* f. *aculeata*. **28.** *Micrasterias rotata* var. *rotata*. **29.** *Micrasterias thomasiana* var. *notata*. **30.** *Micrasterias torreyi* var. *nordestedtiana*. **31, 32.** *Micrasterias truncata* var. *pusilla*. Scale bars: Figs 26, 30–32 = 30 µm; Figs 27–30 = 60 µm.

Material examined. Brazil, Bahia, Camaçari, Rio Pojuca, 16/V/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219756); Candeias, Lagoon BR-324, 12/IX/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219807); Mata de São João, Imbassaí, 26/VII/2009, I.B. Oliveira and J.T. Farias, s/n. (HUEFS 155776); Pojuca, Lagoon near to BA-093, 15/XI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219816); Salvador, Av. Paralela, 31/III/2014, C.W.N. Moura et al. s/n. (HUEFS 219749); São Francisco do Conde, Lagoon BA-523, 15/V/2014, M.A. Santos and A.A. Santos, s/n. (HUEFS 219755); São Sebastião do Passé, Fazenda Caípe, 15/XI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219812); Vera Cruz, Estrada Porcaozinho, 25/VIII/2014, M.A. Santos et al. s/n. (HUEFS 219214).

Notes. *Micrasterias radiosa* var. *ornata* f. *ornata* is very similar to, and can be mistaken with, *M. radiosa* Ralfs var. *ornata* Nordstedt f. *aculeata* (W.Krieger) Croasdale, but it is distinguished by the presence of small spines arranged along the median sinus and the deeper lobular incisions (Bittencourt-Oliveira and Mecenas 1994). Although not so common in floristic surveys, this form occurred in 8 of the 11 municipalities sampled, although we classify it as rare in the MRS (Table 2).

Micrasterias radiosa Ralfs var. *ornata* Nordstedt f. *aculeata* (W.Krieger) Croasdale, 1977

Figure 27

Material examined. Brazil, Bahia, Mata de São João, Imbassaí, 11/I/2009, I.B. Oliveira and C.W.N. Moura, s/n. (HUEFS 155605); Pojuca, Lagoon near to BA-093, 15/XI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219816); Salvador, Parque de Pituaçu, 13/XII/2014, M.A. Santos et al. s/n. (HUEFS 219829); Vera Cruz, Lagoon near to BA-001, 22/IX/2015, M.A. Santos and C.A. Ribeiro s/n. (HUEFS 219238).

Notes. *Micrasterias radiosa* var. *ornata* f. *aculeata* stands out among all other subspecific taxa of *M. radiosa* recorded in this study in having robust spines along the median sinus margins, deeper cellular incisions, and 2–5 denticles on the apical margin of the polar lobe. Among the other taxa of *M. radiosa* recorded in the MRS, this one that had the most restricted distribution, occurring in only 5 municipalities (Table 2).

Micrasterias rotata (Greville) ex Ralfs var. *rotata*, 1844

Figure 28

Material examined. Brazil, Bahia, Camaçari, Rio Capivara, 09/III/2007, I.B. Oliveira et al. s/n. (HUEFS 125557); Itaparica, Engenho, 23/VII/2015, M.A. Santos and C.A. Ribeiro s/n. (HUEFS 219231); Lauro de Freitas, Catu de Abrantes, 02/X/2015, C.A. Ribeiro et al. s/n. (HUEFS 219847); Mata de São João, Jauara Lagoon, 14/VII,/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219765); Salvador, Parque de Pituaçu, 13/VII/2014, M.A. Santos et al. s/n. (HUEFS 219828); Vera Cruz, Estrada Porcaozinho, 22/IX/2015, M.A. Santos and C.A. Ribeiro s/n. (HUEFS 219245).

Notes. Bicudo and Sormus (1982) reported variation in the shape and projection of the polar lobe, opening of the cellular incisions, and lobulation of the basal lobes of *M. rotata* var. *rotata*. However, in the MRS, this taxon was morphologically very homogeneous, showing little or no variation. According to Šťastný (2010), in European lakes the species usually occurs in mesotrophic and acidic (pH < 6.5) environments, where it makes up the periphyton. However, in Brazil this species is reported occurring in both the periphyton and phytoplankton of oligotrophic environments (Melo et al. 2005, Felisberto and Rodrigues 2008). In the MRS, we found *M. rotata* var. *rotata* in fewer than 10% of our samples, and thus, we consider it rare (Table 2).

Micrasterias thomasiana Archer var. *notata* (Nordstedt) Grönblad, 1920

Figure 29

Material examined. Brazil, Bahia: Mata de São João, Lagoon BA-099, 14/II/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219770); Vera Cruz, Lagoon near to BA-001, 23/VII/2015, M.A. Santos and C.A. Ribeiro s/n. (HUEFS 219228).

Notes. *Micrasterias thomasiana* var. *notata* is characterized by cells with a subcircular contour, elongate apical lobe, presence of 2 convergent denticles located at the margin of the apical notch of the polar lobe, and the presence of 3 intumescences located at the base of each semicell, although this last character is variable and may or may not be present, as observed by Santos et al. (2016) and Moresco et al. (2009). In European lakes, Šťastný (2010) reported its occurrence in oligotrophic or mesotrophic, acidic (pH < 6.5) environments, where it was most of the time on underwater substrates or associated with submerged aquatic plants. In the MRS, we classified this variety as rare because it was only recorded in the municipalities of Mata de São João and Vera Cruz (Table 2).

Micrasterias torreyi Bailey ex Ralfs var. *nordstedtiana* (Hieronymus) Schmidle, 1898

Figure 30

Material examined. Brazil, Bahia, Pojuca, Lagoon near to BA-093, 15/VI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219816); São Francisco do Conde, Lagoon BA-522, 07/XI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219826).

Notes. *Micrasterias torreyi* var. *nordstedtiana* differs from the typical variety of the species because it possesses cells that are longer than wide, has 2-denticulate lobes, and the lobes have inflated inner margins partially covering each other. Oliveira (2011) reported variation in the morphology of the polar lobe of material from the

municipalities of Esplanada and Conde, but we found no variation in our MRS specimens; in the MRS, populations were small and very homogeneous. This is the first record of this variety from the MRS, where we consider it rare (Table 2).

***Micrasterias truncata* (Corda) Brébisson ex Ralfs var. *pusilla* G.S.West, 1939**
Figures 31, 32

Material examined. Brazil, Bahia, Camaçari, APA Lagoas de Guarajuba, 09/III/2007, I.B. Oliveira et al. s/n. (HUEFS 125525); Salvador, Avenida Paralela, 31/III/2014, C.W.N. Moura, G.J.P. Ramos, M. A. Santos and A.A. Santos, s/n. (HUEFS 219748); Candeias, Lagoon BR-324, 12/IX/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219803); Lauro de Freitas, Jambeiro, 26/I/2015, M.A. Santos, s/n. (HUEFS 219832); Mata de São João, Lagoon BA-512, 14/VII/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219773); Pojuca, Lagoon near to BA-093, 15/XI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219819); São Francisco do Conde, Lagoon BA-523, 15/V/2014, M.A. Santos and A.A. Santos, s/n. (HUEFS 219752); São Sebastião do Passé, Lagoon BA-512, 15/VI/2014, M.A. Santos and G.J.P. Ramos, s/n. (HUEFS 219811).

Notes. *Micrasterias truncata* var. *pusilla* is a common and widely distributed taxon in Brazil (Araújo et al. 2015). According to Oliveira et al. (2009) and Ribeiro et al. (2015), this variety it is quite polymorphic, but our specimens from the MRS, presented variation only in the morphology of the polar lobe. Some individuals presented apical lobe typical of var. *pusilla*, with a convex apical margin and acuminate extremities. Other specimens presented apical lobe similar to that of *M. abrupta* var. *abrupta*, with rectilinear apical margin and bifurcated extremities. Nemjová et al. (2011), who studied the morphological and molecular differentiation of the species complex of *M. truncata*, observed that Australian strains of *M. truncata* var. *pusilla* were closely related to *M. zeylanica* F.E. Fritsch. Thus, they believed that Australian strains assigned to var. *pusilla* probably are a separate species, and they suggested the need for a future review of the *M. zeylanica*/*M. truncata* var. *pussila* complex originating in Australia. In Brazil, the variety is referred to phytoplankton and the periphyton of oligotrophic and mesotrophic environments (Felisberto and Rodrigues 2005, 2008, Aquino et al. 2014, Silva and Felisberto 2015). Although we found *M. truncata* var. *pusilla* at a low frequency in the MRS, it was one of the most represented, occurring in 8 of the 11 municipalities studied (Table 2).

Discussion

Based on our 275 samples, the richest municipalities in terms of the number of taxa were Mata de São João (24), Camaçari (18), and Vera Cruz (16), while Dias d'Ávila and Itaparica were the least rich, with only 2 and 3 taxa recorded, respectively. The large number of taxa recorded from Mata de São João and Camaçari may be related to the great diversity of aquatic bodies in these municipalities, which happen to be the largest in the MRS, which is reflected in our greater sampling effort in these 2 areas. According to Magurran (1988), the greater the heterogeneity of habitats, the greater the diversity of niches and, consequently, the greater the richness of species.

We found that only *M. pinnatifida* var. *pinnatifida* was considered frequent, whereas 24% of the taxa were classified as occasional and 72% were rare (Table 2). The rarity of species may be due to intrinsic (biological or ecological characteristics that are characteristic of the species) or extrinsic (anthropogenic causes) factors and is generally expressed by species with low relative abundances and restricted geographic distributions (Gaston 1994, Partel et al. 2005, Resh et al. 2005). Urbanization is usually the primary cause of biodiversity loss because it promotes changes in natural environments (McKinney 2006), which increases the risk of species extinction (McKinney 1997, Partel et al. 2005). Thus, the high number of rare taxa in the MRS is possibly closely related to the high rates of urbanization of the region, which in 2010 already reached approximately 98% of urbanized area (Fernandes and Guimarães 2014). Among the municipalities of the MRS, Fernandes and Guimarães (2014) found that Mata de São João, besides having the largest area, had the least urbanization among the municipalities; in our study, this might have influenced the higher number of taxa observed here compared to the entire MRS.

A minimum of 100 samples is required for good sampling effort and a reliable estimate of the distribution pattern of a species (Matteucci and Colma 1982). According to these authors, populations with a regular (uniform) spatial distribution pattern tend to have a high frequency of occurrence, whereas for aggregated (grouped) populations the frequency of occurrence tends to be lower. Thus, our results suggest that in the MRS most of the *Micrasterias* taxa possess aggregate distribution patterns, as more than 70% of them had low frequencies of occurrence (recorded from < 10% of the 275 samples; Table 2). This is true for the MRS as a whole but not for the municipalities individually, as the number of samples collected in each of them was fewer 100, which, according to Matteucci and Colma (1982), does not allow us to make safe inferences about the distribution pattern of *Micrasterias* within each of these areas.

From the data obtained, a Venn diagram (Fig. 33) was generated with the purpose of evaluating the distribution of *Micrasterias* taxa in the 5 largest APAs of the MRS, APA Bahia de Todos os Santos, APA Joanes-Ipitanga, APA Lagoas de Guarajuba, APA Litoral Norte, and APA Rio Capivara. We found that of the 29 taxa inventoried, only 5 were common in the APAs listed above: *M. alata* var. *alata*, *M. borgei* var. *borgei*, *M. furcata* var. *furcata*, *M. laticeps* var. *laticeps* and *M. pinnatifida* var. *pinnatifida* (Table 3).

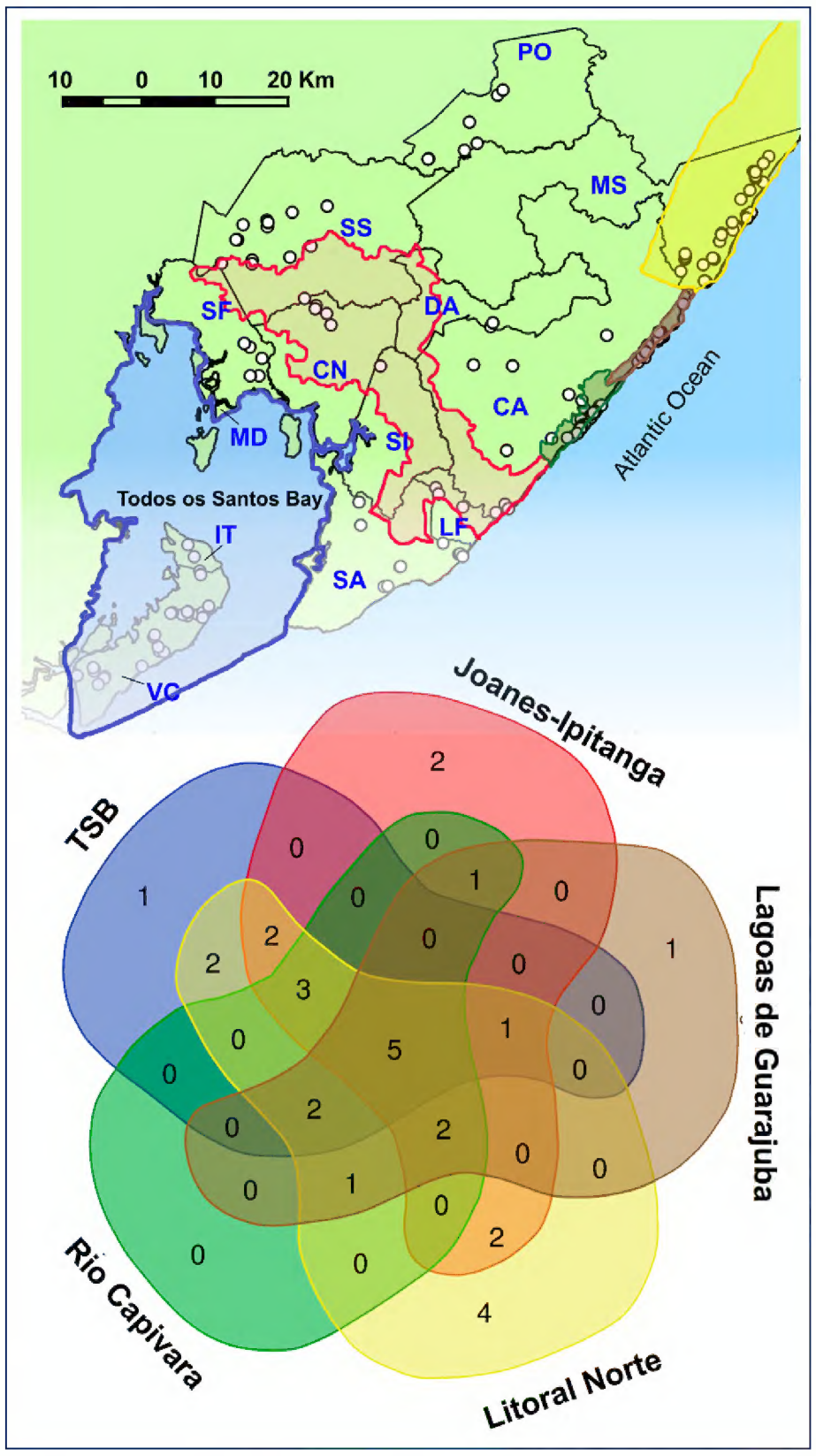


Figure 33. Venn diagram showing the distribution of *Micrasterias* among the most representative Environmental Protection Areas (APA Baía de Todos os Santos (TSB), APA Joanes-Ipitanga, APA Lagoas de Guarajuba, APA Litoral Norte, APA Rio Capivara) of the Metropolitan Region of Salvador, Bahia, Brazil.

The APA Litoral Norte, which was represented in our study only by the municipality of Mata de São João, was the most species-rich, with 24 taxa found and with 4 taxa found in no other areas: *Micrasterias denticulata, M. laticeps* var. *ampliata, M. papillifera* var. *glabra*, and *M. quadridentata*. The APA Joanes-Ipitanga, although it is large (ca 65,500 ha) and includes part of the municipalities of Camaçari, Candeias, Dias d'Ávila, Lauro de Freitas, São Francisco do Conde, São Sebastião do Passé, and Salvador (INEMA 2018), had only 18 taxa, of which only *M. torreyi* var. *nordestedtiana* and *M. arcuata* var. *arcuata* were exclusive.

The APAs Baía de Todos os Santos (which in addition to the islands belonging to Candeias, Simões Filho, São Francisco do Conde, and Salvador, encompasses the islands of Madre de Deus and Itaparica) and Lagoas de Guarajuba (municipality of Camaçari) had 16 and 13 taxa, respectively, of which *Micrasterias furcata* var. *dichotoma* occurred exclusively in the first, and *M. americana* var. *bahiensis* exclusively in the second (Table 3). On the other hand, the APA Rio Capivara (Camaçari) did not possess any exclusive taxa.

According to data from INEMA (2018), the APAs of the MRS are subject to various environmental conflicts, such as the release of domestic and industrial effluents into aquatic ecosystems, deforestation, fires, unplanned real estate occupation, inadequate disposal of solid waste, and illegal extraction of sand, among others. Such activities have compromised the preservation of these areas and directly or indirectly the availability and quality of the aquatic habitats contained therein, causing serious problems such as siltation, heavy metal contamination, increases of water temperature and turbidity, and eutrophication, among others, which interfere in the balance of the ecosystem and consequently its biodiversity (Mota 2003, Agostinho et al. 2005, INEMA 2018).

When comparing our data (Table 1) with previous inventories in the MRS by Oliveira et al. (2009, 2017) and Santos et al. (2016), it is evident that our study contributes the most to the knowledge of the diversity and geographic distribution of *Micrasterias* because it surveyed a greater number of municipalities (11) and recorded a greater number of taxa (29).

The diversity of *Micrasterias* found in Mata de São João was similar to that found by Oliveira et al. (2017), who reported 28 taxa occurring in APA Litoral Norte, of which 23 occurred in the aforementioned municipality; 3 taxa listed by the authors were not found in the present study: *M. prescottiana* C. Bicudo and Sormus, *M. truncata* (Corda) Bréb. *ex* Ralfs var. *truncata* f. *gibbosa* Thomasson and *M. arcuata* var. Thus, we increase the number of *Micrasterias* present in Mata de São João, from 23 to 27, of which *M. quadridentata*, *M. radians*, *M. rotata* var. *rotata* and *M. thomasiana* var. *notata* are new occurrences for the area. Comparing our data with those obtained by Oliveira et al. (2009) for the APAs Lagoas de Guarajuba and Rio Capivara (both in the municipality of Camaçari), there was an increase in the number of taxa from 14 to 18, with *M. abrupta*, *M. radians*, *M. radiosa* var. *radiosa* and *M. radiosa* var. *ornata* f. *ornata* being new occurrences for the area. Finally, considering the study by Santos et al. (2016) for Itaparica Island, with the exception of *M. furcata* var. *dichotoma*, which was cited as an addition to the desmid flora of Brazil, all of the other taxa also occur in other municipalities of the MRS.

Final remarks. The identification of species, especially rare species, are extremely important for understanding the structure and dynamics of biological communities. This knowledge makes it possible to identify priority areas for conservation, as well as to develop actions aimed at protecting biodiversity (Lyons et al. 2005, McCreadie and Adler 2008). In our study, we highlight the importance of the MRS in understanding the biodiversity and geographic distribution of *Micrasterias*. We also emphasize the importance of the conservation of aquatic bodies in the MRS for the maintenance of biological diversity,

Table 3. Distribution of *Micrasterias* among the most representative Environmental Protection Areas in RMS, highlighting the common taxa between APAs and those that occurred exclusively in each of them.

	RMS Enviroment Protection Area	*Micrasterias* species	
		Total	**Species**
Exclusive taxa	TSB	1	*M. furcata* var. *dichotoma*
	Joanes-Ipitanga	2	*M. torreyi* var. *nordestedtiana* *M. arcuata* var. *arcuata*
	Lagoas de Guarajuba	1	*M. americana* var. *bahiensis*
	Litoral Norte	4	*M. denticulata* var. *denticulata* *M. quadridentata* *M. papillifera* var. *glabra* *M. laticeps* var. *ampliata*
Common taxa	TSB + Joanes-Ipitanga + Lagoas de Guarajuba + Litoral Norte + Rio Capivara	5	*M. furcata* var. *furcata* *M. pinnatifida* var. *pinnatifida* *M. borgei* var. *borgei* *M. laticeps* var. *laticeps* *M. alata* var. *alata*
	TSB + Joanes-Ipitanga + Lagoas de Guarajuba + Litoral Norte	1	*M. radiosa* var. *ornata* f. *ornata*
	Joanes-Ipitanga + Lagoas de Guarajuba + Rio Capivara	1	*M. mahabuleshwarensis* var. *ampullacea*
	Lagoas de Guarajuba + Litoral Norte + Rio Capivara	1	*M. arcuata* var. *subpinnatifida*
	TSB + Joanes-Ipitanga + Litoral Norte + Rio Capivara	3	*M. rotata* var. *rotata* *M. mahabuleshwarensis* var. *mahabuleshwarensis* *M. abrupta* var. *abrupta*
	TSB + Lagoas de Guarajuba + Litoral Norte + Rio Capivara	2	*M. foliacea* var. *foliacea* *M. radiosa* var. *elegantior*
	Joanes-Ipitanga + Lagoas de Guarajuba + Litoral Norte +Rio Capivara	2	*M. truncata* var. *pusilla* *M. laticeps* var. *acuminata*
	TSB + Joanes-Ipitanga + Litoral Norte	2	*M. radians* *M. radiosa* var. *radiosa*
	TSB + Litoral Norte	2	*M. radiosa* var. *ornata* f. *aculeata* *M. thomasiana* var. *notata*
	Joanes-Ipitanga + Litoral Norte	2	*M. arcuata* var. *expansa* *M. arcuata* var. *robusta*

which is seriously threatened as a result of increasing urbanization in the MRS.

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Authors' Contributions

MAS, CEMB, and CWNM wrote the manuscript; MAS and CWNM participated in the fieldwork.

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